1978 C-b ANNUAL REPORT

VOLUME 2

ENVIRONMENTAL ANALYSIS

C-B SHALE OIL PROJECT
OCCIDENTAL OIL SHALE, INC., LESSEE
751 HORIZON COURT
GRAND JUNCTION, COLORADO 81501

APRIL 20, 1979

9.

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ENVIRONMENTAL ANALYSIS

April 20, 1979

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C·b Shale Oil Project
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FOREWORD

The 1978 C-b ANNUAL REPORT is submitted to fulfill the requirements of the Oil Shale Lease as stated in Section 16(b) of the Lease, Section 1.(C)(4) of the Lease Environmental Stipulations, and Condition of Approval (No. 3) of the Detailed Development Plan. This report consists of the following volumes:

Volume 1	-	Summary of Development Activities, Costs and Environmental Monitoring
Volume 2	-	Environmental Analysis
Appendix 2A	-	Volume 2 Supporting Data
Appendix 2B	-	Volume 2 Time Series Plots

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1.0 INTRODUCTION AND SUMMARY

1.1 Scope

The Environmental Baseline Period for Oil Shale Tract C-b covered the period from November 1, 1974, to October 31, 1976. Results have been reported in nine Quarterly Data Reports, eight Quarterly Summary Reports, Annual Summary and Trends Report (1976), and a 5-volume Environmental Baseline Program, Final Report (1977), all submitted to the Area Oil Shale Supervisor.

From November 1, 1976 through August 31, 1977, the C-b Tract was under a period of suspension of the Federal Oil Shale Lease. This period was known as the Interim Monitoring Phase. Environmental data for this time period were submitted to the Area Oil Shale Office (AOSO) on October 14, 1977 (Interim Monitoring Report #1). The Interim Monitoring Period was later extended by the AOSO to cover the period from September 1, 1977 through March 31, 1978. Data for this time period were submitted to the AOSO on May 15, 1978 (Interim Monitoring Report #2). The Development Monitoring Program was initiated in April 1978. Final approval of the Development Monitoring Plan by the AOSO is expected in the near future. Data for the time period from April 1978 through September 1978 were submitted on January 15, 1979 to the AOSO. Subsequent semi-annual data reports are scheduled for delivery every January 15 and July 15.

This is the first environmental analysis of data for Oil Shale Tract C-b since the final report of the Environmental Baseline Program was published in 1977.

This report, 1978 C-b Annual Report, Volume 2, Environmental Analysis, presents analyses in all of the broad environmental areas identified in the Development Monitoring Program for data collected since November 1976. Because there is always a data-lag and reduction problem, analyses for some studies are based on data only through September 1978. This report is not as detailed or comprehensive as the 5-volume Environmental Baseline Program, Final Report (1977). It need not be. The Interim Monitoring and Development Monitoring Programs have been reduced and changed from the Environmental Baseline Monitoring Program in many areas. Therefore, emphasis is now placed on key indicators of environmental quality and/or change which are evaluated in this report.

The report outline follows closely the outline of the Development Monitoring Program document for ease of cross reference.

1.2 Purpose

The purpose of this report is to fulfill the requirement of the lease to provide the Area Oil Shale Supervisor's Office with an annual report of environmental analyses. The Development Monitoring Plan states the following objectives with respect to environmental monitoring:

> The purposes or objectives of environmental monitoring as defined in Section 1 (C) of the Stipulations are to provide: 1) a record of changes from conditions existing prior to development operations,

as established by the collection of baseline data; 2) a continuing check on compliance with the provisions of the Lease and Stipulations, and all applicable Federal, State and local environmental-protection and pollution control requirements; 3) timely notice of detrimental effects and conditions requiring correction; and 4) factual basis for revision or amendment of the Stipulations.

This report documents the analyses and conclusions relative to assessment of potential environmental impacts and trends that may be indicated in the collected data. Since development activities were not started until 1978, much of the data and analyses may be considered as a continuation of environmental baseline and background definition.

1.3 Summary

Environmental monitoring and analyses are continuing on Oil Shale Tract C-b. Development activities commenced within the past year have resulted in increased activity on the Tract in the form of off-road vehicular use, facility construction, shaft sinking, and traffic into and out of the area. All activity has been conducted within strict adherence to environmental, permit, and lease regulations. Environmental impacts, where they exist, have been confined to the immediate area and within limits defined in the Detailed Development Plan.

The following paragraphs present brief highlights of the report sections. A foldout map showing all of the C-b Tract Development Monitoring sites is provided in a jacket in the back of this report.

1.3.1 Tract Photography

A tract surface and aerial photography program has been initiated to provide permanent records of change and surface disturbance. Sufficient time lapse has not occurred to identify other than purely qualitative effects of wet or dry years on vegetation from the aerial photographs.

1.3.2 Indicator Variables

The Development Monitoring Program has been brought into sharper focus with the identification of Class 1 indicator variables. These are key environmental variables collected at representative stations in at least a monthly sampling frequency. Time series plots, largely generated by the computer from the data base, are presented in Appendix B. These plots will be maintained and updated monthly (as a goal) to provide visual analyses of trends and interrelationships.

1.3.3 Hydrology

Regarding hydrology, analyses of USGS Gauging Stations surface water quality and quantity data reveal no adverse trends for indicator variables either over time or between station locations. Streamflow records on

Piceance Creek above and below the C-b Tract show no change in mean annual flows. One-day minimum flow averages may be less than one cubic foot per second (cfs). Maximum peak flows recorded since baseline were 520 cfs on July 19, 1977 upstream from the C-b Tract, and 492 cfs on September 3, 1977 downstream from the Tract.

A few isolated statistical trends in water quality parameters (sulfate, pH, and arsenic) were noted for some water quality data obtained from springs and seeps. However, suspected spurious values as well as paucity of data discount the significance of these at this time. Any trends at this point in time of very limited development activity would be an indication of a trend in the baseline data.

Water quality and level data for selected alluvial wells and indicator variables showed no overall trends with time from baseline. Comparison of parameter mean values between stations showed no significant differences for most comparisons. The notable exception is for specific conductance which showed differences in four of six comparisons. Water level in bedrock wells showed no trends over time.

1.3.4 Aquatic Ecology

It is useful to relate the previous hydrologic discussion to qualitative aquatic ecological considerations as they pertain to Piceance Creek. Piceance Creek as an ecosystem has been characterized as a "productive, disrupted system existing under marginal physical and chemical conditions," imparting the impression of "marginal, low quality aquatic environment" (Woodling and Kendall (1974)).

Biological production in Piceance Creek is presently restricted by a combination of natural and man-caused factors. Natural factors limiting biological production are the unstable nature of most of the streambed and irregular discharge. Loose sand, silt and mud comprise much of the substratum. These materials are easily shifted about by currents, particularly those associated with runoff of snowmelt and high intensity thunderstorms. In times of low flow, much of the streambed becomes dewatered, thus exposing biota to possible desiccation.

Land use practices along Piceance Creek intensify the adverse effects of some natural limiting factors. Cattle grazing has probably reduced the vegetative cover of the watershed and thereby contributed to the irregularities in stream flow. Cattle trample stream banks and willow growth along the streams and thus destroy cover for fishes. Irrigation diversions dewater sections of Piceance Creek so that they may be intermittently dry, and return water probably leaches salts from the fields and increases the load of dissolved solids. Ammonia and nitrogen may be leaching in significant amounts from manure emanating from winter feeding concentration of cattle along Piceance Creek.

The water of Piceance Creek is high in dissolved salts relative to the "average" North American stream; however, the load in Piceance Creek is not unusually great for streams in semi-arid western localities. Low quality-high salinity

groundwater from deep aquifers reaches Piceance Creek via springs discharging into it, especially in reaches downstream from Ryan Gulch. Although the salinity of lower Piceance Creek is greater than in upstream reaches, there is no unambiguous evidence that salinity is limiting total biological production.

1.3.5 Air Quality

With regard to air quality, gaseous constituents measured include sulfur dioxide, hydrogen sulfide, carbon monoxide, ozone, and oxides of nitrogen; total suspended particulates have also been measured. For the overwhelming majority of the time, SO_2, H_2S, and CO have indicated background levels below the lower level of significance of the instruments. Only for ozone and total suspended particulates have significant values been measured. Ozone-concentration shifts to high values show correlation with weather-related meteorological parameters. High particulate concentrations to date are judged to be due solely to fugitive dust. Time series plots do not identify any discernible trends in either gaseous constituents or particulates over time, except for some seasonal variations in particulates. Particulate concentrations are usually highest in spring and fall with minimums in winter. No specific dependence of concentrations on wind speed or direction has been noted.

Mean annual visual range in 1978 was 130 km (81 miles), with a seasonal Spring minimum of 126 km (78 miles) and Fall maximum of 138 km (86 miles). No significant change in the annual mean has been noted since the 1975-1976 measurements.

1.3.6 Meteorology

Climatological records indicate an annual mean temperature of 6-7° C over the past four years. Time series analyses of monthly means has demonstrated no trend in long-term mean values. Cold air drainage results in winter minima in Piceance Valley near -43° C. Although 1977 was the wettest of the four years (35.7 cm), its distribution was such that it came too late in the year to be a major influence on productivity. Lightest annual precipitation was 23.6 cm in 1976. Peak storm intensities reached 4.3 cm precipitation on September 3, 1977.

Predominate winds on Tract continue to be from the south-southwest with Spring and Summer showing higher wind speeds (5-8 m/sec) than Fall and Winter (1-3 m/sec) at the 10-meter level above surface. Winds from the Tract direction generally become channeled by Piceance Valley walls toward the WNW downstream direction of Piceance Creek during late afternoon and night; directions reverse in daytime. Air is typically stable during night and early morning and unstable in late morning and afternoon.

1.3.7 Noise

The environmental noise program deals with both traffic and tract-generated noise levels. The discrete (weekly) traffic noise level

measurements indicated noise levels approximately nine dbA above baseline peaks. Continuous noise measurements (every sixth day) indicate no significant increases due to the tract activities in average noise levels for two 12-hour periods (7 p.m.-7 a.m. and 7 a.m.-7 p.m.).

1.3.8 Wildlife Biology

Maximum weekly counts of deer observed along Piceance Creek since baseline have always occurred in spring and have varied from 1,512 in 1976 to 1,034 in 1978 with 1975 and 1977 values intermediate to these. Road kills in any week usually vary from less than 1% to 1.5% of those counted in any given week. A total of 125 deer were killed along the road from September 1977 to May 1978. Use of company buses has been the principal mitigative measure in reducing traffic on Piceance Creek road. Regarding natural deer mortality in lateral draws and gulches, fawns have comprised 80% of deer mortality each year. Age class composition for mule deer wintering near the tract are as follows: 79 fawns per 100 does, 26 bucks per 100 does, and 64 fawns per 100 adults.

Regarding medium-sized mammals, fewer coyotes and more cottontail rabbits were noted in 1978 than in 1977.

As with previous sampling periods, greater avian songbird diversity has been noted in pinyon-juniper woodlands as opposed to chained pinyon-juniper; similarly more mourning doves were found in the unchained habitats. Nesting raptors in the tract vicinity in 1978 consisted of red-tailed hawks and great-horned owls. Although bald eagles have been observed in the tract vicinity, none nested or remained in the area; they were merely flying through. No threatened or endangered species were found on or near the Tract.

1.3.9 Vegetation

Monitoring data suggest that over the past four years there have been no major changes in species composition or community structure in the chained rangelands. The general trend has been for a slight increase in total cover and also for an increase in the density of big sagebrush. These changes are closely related to the successional characteristic of the chained rangelands. The trend for increasing shrub cover and density is likely to continue until the tree saplings mature into tree-size individuals.

The production patterns within the vegetation types observed during the Development Monitoring period are the same as those observed during the baseline period. Utilization continues to be seasonal and by mid-growing season is nearly non-detectable because of livestock use patterns. Observed differences in productivity between intensive study plots appear to be more related to site differences than to any development-related activities. Herbaceous production is closely related to precipitation; significant differences in production between years are related to differences and fluctuating patterns of precipitation in this semi-arid region. Fertilization of upland chained areas appears to result in an increase in herbaceous production. Because of a limited sample

size and high data variability, the differences between fertilized areas and control areas were not significant. Shrub production and utilization (bitterbrush and mountain mahogany) for this past year differed markedly from those of 1976-1977 in that production was lower and utilization by mule deer was much higher. Precipitation distribution was more favorable to productivity in 1978 than in 1977.

Revegetation monitoring will be conducted on sites which have undergone surface disturbance and on future raw-shale disposal sites. Erosion control and rehabilitation are discussed in Volume 1, including the reclamation activity-schedule defining affected areas, disturbance timetable, reclamation time span, and disturbed acreage.

1.3.10 Ecosystem Interrelationships

Ecosystem interrelationship studies have been initiated as a means of assessing the potential impact of environmental perturbations resulting from development activity. Quantitative studies to date included: (1) effects of climatic variations on herbaceous productivity; (2) effects of traffic, climate, and size of mule-deer herd on deer road-kill; and (3) effects of urbanization on watershed hydrologic response time. Principal results established were as follows: (1) herbaceous productivity correlated best with precipitation in April-May-June and total precipitation of the previous year; (2) deer road-kill correlated best with deer road count; (3) a lag time of 5.5 hours was demonstrated to exist currently between a precipitation event and peak flow on Piceance Creek below the tract; future analyses will determine potential effects of urbanization on this lag or response time.

1.3.11 Items of Prehistoric and Historic Interest

Recent developments regarding items of prehistoric or historic interest have been primarily associated with a planned route for a powerline from Meeker to the Tract. One prehistoric site and five isolated "finds" were located near the proposed right-of-way; mitigation will be accomplished by avoiding these sites through minor rerouting.

1.3.12 Health and Safety

With regard to health and safety, accident frequency analyses and inspection reports (Mine Safety and Health Administration (MSHA) and Colorado Division of Mines (CDM)) are included in the Development Monitoring Plan and its reports. At C-b based on 442,218 man-hours worked during 1978, there were three lost-time accidents totaling seven lost-time days. The site injury incidence rate was 1.35 (incidents per 200,000 man-hours), and the severity measure was 3.16. These compare favorably with the national averages for underground mines of 16.32 and 23.0 respectively.

2.0 TRACT DEVELOPMENT SCHEDULE AND MAPS

2.1 Development Schedule

The proposed development schedule is presented as Figure 3-1 of Volume 1 of this report. A comparison of proposed vs. actual schedules for calendar 1978 is presented as Figure 3-2 of Volume 1.

2.2 Maps

A fold-out map depicting monitoring site locations for Development Monitoring is included in the jacket inside the back cover of this report. Four-digit computer codes are also shown on the map; comparisons of computer codes and "conventional" site locations are included in Appendix A2.2.

Related maps are included in each chapter as appropriate.

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3.0 TRACT PHOTOGRAPHY

3.1 Scope and Rationale

Section 1 (C) of the Environmental Lease Stipulations requires that the Lessee conduct monitoring programs to measure perceptible changes from baseline conditions. Toward this end both a surface and an aerial photography program have existed since baseline. For the surface program, color photos are obtained annually. For the aerial program, black and white and color/infrared are obtained annually and color once every five years.

3.2 Surface Program

3.2.1 Objectives

The objectives of the surface program are to provide:
1) a record of changes from conditions existing prior to development operations;
2) visual evidence of successional changes in the ecosystem;
3) a visual record of surface disturbance;
4) an historic account of surface development; and
5) a visual basis for revision or amendment of the Stipulations.

3.2.2 Experimental Design

Thirty-one points have been selected for Development Monitoring from which a 360^{0} pan is photographed on a yearly basis. (Figure 3.2.2-1). A 35mm camera with an f 1.8, 55mm lens using Ektachrome Professional Type R, ASA 200 film is used. Once each year in June between 10:00 a.m. and 2:00 p.m. on cloudless days, a 360^{0} photo pan is taken from each of the thirty-one photo map stations.

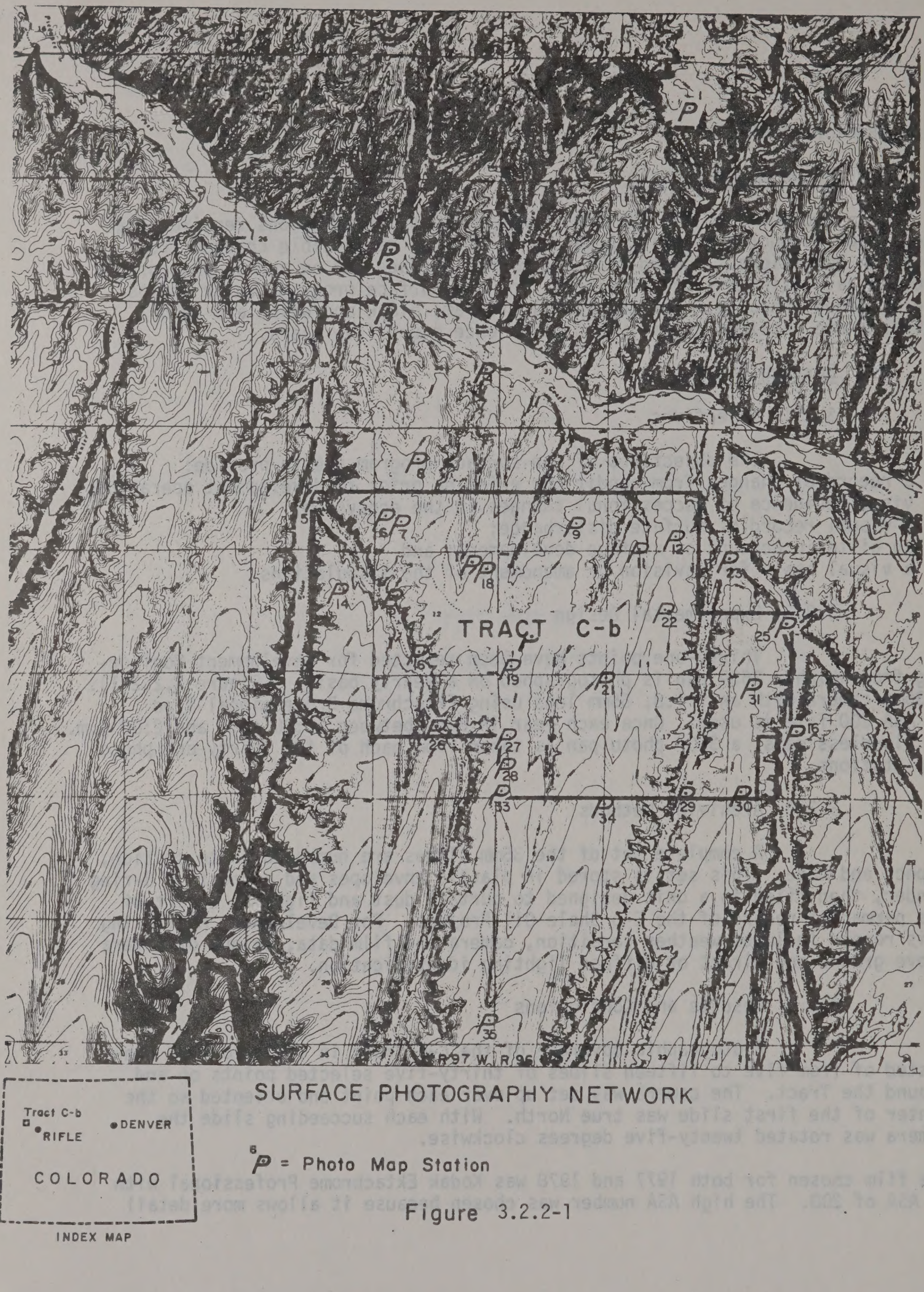
3.2.3 Archiving Methods

A complete set of the 35mm slides are numbered as to station, aspect and date. This set is stored in plastic envelopes and bound in a 3-ring binder, then filed in a unit designed to curtail dust and light as a part of the permanent record of the C-b Shale Oil Project. For Development Monitoring this record includes weather condition, camera and film data, height of camera above ground and direct or diffuse lighting identification.

3.2.4 Results and Conclusions

Photographic coverage of the C-b Tract in 1977 and 1978 consisted of from five to fifteen slides of thirty-five selected points on and around the Tract. The camera was set up over each point and oriented so the center of the first slide was true North. With each succeeding slide the camera was rotated twenty-five degrees clockwise.

The film chosen for both 1977 and 1978 was Kodak Ektachrome Professional with an ASA of 200. The high ASA number was chosen because it allows more detail



SURFACE PHOTOGRAPHY NETWORK

^{6}P = Photo Map Station

Figure 3.2.2-1

to be visible in shaded areas and reduces the "blocking up" that occurs with a slower film. Since this film has a very high sensitivity to blues, an 81A filter was utilized to cut the blue cast and a polarizing filter was placed over this to give better haze penetration. The film was slightly under-exposed to give a more dense slide with an increased dye concentration; this technique extends the life of the slide when properly stored.

During 1977, photo points 4, 10, 13, 14 and 26 were not recorded due to snowfall (9 November - 16 November) or mechanical failure. During 1978, photo points 2, 4, and 13 were not recorded due to mechanical failure.

Sufficient time lapse has not occurred to identify other than a wet or dry year.

3.3 Aerial Program

3.3.1 Objectives

The objectives of aerial photographic coverage of the C-b Tract and a one-mile buffer utilizing vertical viewing are to provide:

1) a record of changes from conditions existing prior to development operations, as established by the collection of baseline data;
2) timely notice of certain detrimental effects and conditions requiring correction;
3) general vegetative conditions (correlated with Biology);
4) inventory of site physical conditions; and
5) subsidence details.

3.3.2 Experimental Design

For Development Monitoring, the scale is 1:6000. Film is black and white, color and color/infrared. Resolution is such that an object three feet across on the horizontal plane can be seen with the unaided eye. Flight lines are flown from West to East and photography taken from 10:00 a.m. to 2:00 p.m. on cloudless days. Side overlap of 40-50% and fore-and-aft overlap of 60% between photographs are to be specified. Aerial photographs will show visible ground control points as 3' x 12' white crosses on established section corners within the C-b Tract.

Vertical aerial photography is obtained on or about the 15th of June. Frequency is annually for black and white and color/infrared and once every five years for color.

3.3.3 Methods

Regarding archiving, one set of color prints is used for construction of a mosaic; and one set of black and white, color, and color/infrared is stored in a unit designed to curtail dust and light as a part of the permanent record of the C-b Shale Oil Venture. The annual record during Development Monitoring includes weather conditions, camera and film data, height of camera above ground and information on direct or diffuse lighting identification.

An uncontrolled color mosaic for the June 1974 flight is on display at Occidental's Grand Junction offices. The next color mosaic will be compared with June 1974 mosaic to identify major areas of change and a map indicating changes prepared.

Stereo pairs will be utilized to examine the most significant major changes in more detail. These results will be documented in future analysis reports.

3.3.4 Results and Conclusions

The results of the 1977 color aerial photography were such that an uncontrolled mosaic could not be assembled due to severe drift in flight lines. Prints have been archived in accordance with the above described archiving techniques. Vertical aerial photography was not obtained by C-b in 1978. Previous arrangements were made with the EPA to supply the C-b Shale Oil Project with aerial photography. A 1:34000 print was supplied in early 1979 as overflown in September 1978. This print will be archived in accordance with the Development Monitoring Program.

4.0 INDICATOR VARIABLES

Indicator variables are selected monitored environmental parameters that can be expected to provide the earliest clues of potential change in the baseline environment. This section identifies the indicator variables selected for environmental disciplines of hydrology, air quality and meteorology, noise, and biology that will be observed most closely.

4.1 Role in Impact Assessment

Efficient monitoring of environmental quality requires close observation of a few key variables. This includes those variables that are: 1) most sensitive to change in quality; 2) indicators of natural or climatic change; and 3) subject to Federal and State standards because of concern for human health and public welfare. For these reasons the Development Monitoring Plan has identified and emphasized in the collection plan key indicator variables in each of the environmental disciplines.

Close observation of the identified key indicator variables requires early data reduction and analysis in order to flag changes or adverse time-trends in the observations. Visibility is provided by maintaining current time-series plots of the key variables. Impact of development activity is also assessed through statistical comparison of data collected near development and control sites. If trends and differences signal the probable occurrence of adverse environmental impact, additional and increased monitoring will be triggered. (Referred to as Systems Dependent Monitoring.) At present, no Systems Dependent Monitoring has been "triggered."

4.2 Identification of Class 1 Indicator Variables

Indicator variables have been identified in the Development Monitoring Plan as a subset of the monitored environmental parameters. However, the combinations of indicator variables with the number of collection stations exceed 1000. Therefore, Class 1 Indicator Variables have been identified in order to further reduce the number of parameter-site combinations to a realistic quantity (171) for the purpose of close observation. Class 1 Indicator Variables are key environmental variables collected at representative stations on at least monthly frequency. Time series plots will be maintained and updated monthly for these Class 1 Indicator Variables.

This section identifies only the Class 1 Indicator Variables. However, all monitored variables are included in the data reports and the following chapters of this Annual Report.

4.2.1 Tract Photography

Tract photography is to be carried out annually under a surface program and an aerial program as defined in the Development Monitoring Program. While the photographs provide permanent records of existing conditions, no photo interpretations have been made at this time.

Therefore, no Class 1 Indicator Variables associated with tract photography are identified.

4.2.2 Hydrology

Class 1 Indicator Variables for hydrology are identified in Table 4.2.2-1. The number of collection sites has been screened to four major USGS Gauging Stations, four springs and seeps, and four alluvial wells for this group. Parameters are collected either daily or monthly as indicated by the codes in the table. For cross-referencing ease, Table 4.2.2-2 presents the table numbers in Appendix B where these time-series data are presented under separate volume.

4.2.3 Air Quality and Meteorology

Class 1 Indicator Variables and stations for air quality and meteorology are identified in Table 4.2.3-1. Collection frequency for those parameters coded with D is continuous; hourly averages are reported in the data reports. Daily averages and peaks calculated from the hourly averages are used in the time-series plots for these variables. Daily totals will be plotted for those coded with T. Table 4.2.3-2 cross-references the time-series plots.

4.2.4 Noise

Noise is measured at two stations as decibel level. Class 1 Indicator Variables are peak measurements of background noise level for daytime (0700 through 1900 hours) and for nighttime (1900 through 0700 hours). These are shown in Tables 4.2.4-1 and 4.2.4-2.

4.2.5 Biology

Much of the biology data collection and analysis are on a seasonal or annual time frequency. These data and analyses are important indicators for possible oil shale development environmental impact. However, under the definition of Class 1 Indicator Variables as those with at least monthly collection, a much smaller set of biological environmental parameters are identified. These are shown in Tables 4.2.5-1 and 4.2.5-2. Microclimate data are collected twice monthly indicated by 2M in the first table. Monthly and weekly observation frequency are shown with M and W respectively in the tables.

TABLE 4.2.2-1

HYDROLOGY CLASS 1 INDICATOR VARIABLES

VARIABLE	MAJOR U.S.G.S. WU07	WU61	WU58	WU22	SPRINGS AND SEEPS WS01	WS03	WS06	WS07	ALLUVIAL WELLS WA03	WA05	WA06	WA08
1. Ammonia	M	M	M	M								
2. Boron	M	M	M	M								
3. Fluoride	M	M	M	M								
4. Total Dissolved Solids	M	M	M	M								
5. Arsenic	M	M	M	M								
6. Sediment	M	M	M	M								
7. Precipitation	M	M	M	M								
8. pH	D	D	D	D	M	M	M	M	M	M	M	M
9. Temperature	D	D	D	D	M	M	M	M	M	M	M	M
10. Flow	D	D	D	D								
11. Conductivity	D	D	D	D	M	M	M	M	M	M	M	M
12. Dissolved Oxygen	D	D	D	D	M	M	M	M				
13. Level									M	M	M	M

NOTES: Frequency of data sampling is coded: D for daily average of continuous sampling; M for monthly samples.

TABLE 4.2.2-2

HYDROLOGY CLASS 1 INDICATOR VARIABLE TIME-SERIES INDEX

VARIABLE	MAJOR U.S.G.S. WU07	WU61	WU58	WU22	SPRINGS AND SEEPS WS01	WS03	WS06	WS07	ALLUVIAL WELLS WA03	WA05	WA06	WA08
1. Ammonia	B5.2.1-1	-2	-3	-4								
2. Boron	-5	-6	-7	-8								
3. Fluoride	-9	-10	-11	-12								
4. Total Dissolved Solids	-13	-14	-15	-16								
5. Arsenic	-17	-18	-19	-20								
6. Sediment	-21*	-22*	-23*	-24*								
7. Precipitation	-25*	-26*	-27	-28								
8. pH	-29	-30	-31	-32	B5.2.2-1*	-2*	-3*	-4*	B5.3.1-1*	-2*	-3*	-4*
9. Temperature	-33	-34	-35	-36	-5*	-6*	-7*	-8*	-5*	-6*	-7*	-8*
10. Flow	-37	-38	-39	-40								
11. Conductivity	-41	-42	-43	-44	-9*	-10*	-11*	-12*	-9*	-10*	-11*	-12*
12. Dissolved Oxygen	-45	-46	-47	-48	-13*	-14*	-15*	-16*				
13. Level									-13	-14	-15	-16

NOTES: * Plots not included (Insufficient Data)

TABLE 4.2.3-1

AIR QUALITY AND METEOROLOGY CLASS 1 INDICATOR VARIABLES

VARIABLE	SAMPLING STATIONS						
	AB20	AA23	AB23	AC20	AD42	AD56	AREA
1. SO_2	D		D				
2. H_2S	D		D				
3. O_3	D		D				
4. NO_x	D		D				
5. NO_2	D		D				
6. CO	D		D				
7. Particulates (every 3rd day)	T		T		T	T	
8. WS - 10m	D	D			D	D	
9. WD - 10m	D	D			D	D	
10. WS - 30m		D					
11. WD - 30m		D					
12. RH			D				
13. TEMP - 10m	D		D		D	D	
14. PRESS			D				
15. SOLAR			T				
16. ΔTEMP - (60m-10m)		D					
17. PRECIPITATION	T		T				
18. EVAPORATION			T				
19. INV HT				D			
20. MIX HT				D			
21. VISUAL RANGE (every 6th day)							VR

NOTES: Frequency of sampling is continuous for all variables except visual range. Daily averages with min and max hourly values are plotted for those variables coded with D. Daily totals are plotted for those coded with T.

TABLE 4.2.3-2

AIR QUALITY AND METEOROLOGY CLASS 1 INDICATOR VARIABLE TIME-SERIES INDEX

VARIABLE	SAMPLING STATIONS AB20	AA23	AB23	AC20	AD42	AD56	AREA
1. SO_2	B6.2.1-1		-2				
2. H_2S	-3		-4				
3. O_3	-5		-6				
4. NO_x	-7		-8				
5. NO_2	-9		-10				
6. CO	-11		-12				
7. Particulates (every 3rd day)	B6.2.2-1		-2		-3	-4	
8. WS - 10m	B6.3.2-1	-2			-3	-4	
9. WD - 10m	-5	-6			-7	-8	
10. WS - 30m		-9					
11. WD - 30m		-10					
12. RH			B6.3.1-1				
13. TEMP - 10m	-2		-3		-4	-5	
14. PRESS			-6				
15. SOLAR			-7				
16. ΔTEMP - (60m-10m)		-8					
17. PRECIPITATION	-9		-10				
18. EVAPORATION			-11				
19. INV HT				B6.3.2-11			
20. MIX HT				-12			
21. VISUAL RANGE (every 6th day)							B6.2.3-1*

* Plots not included (Insufficient Data)

TABLE 4.2.4-1

NOISE CLASS 1 INDICATOR VARIABLES

VARIABLE	SAMPLING STATIONS NA09	NB19
1. Daytime Noise (0700-1900)	P	P
2. Nighttime Noise (1900-0700)	P	P

NOTES: Sampling Frequency is continuous with peak db for the time interval coded with P.

TABLE 4.2.4-2

NOISE CLASS 1 INDICATOR VARIABLE TIME-SERIES INDEX

VARIABLE		SAMPLING STATIONS NA09	NB15
1. Daytime Noise (0700-1900) 2. Nighttime Noise (1900-0700)	COMBINED	B7.2.1-1*	B7.2.2-1

* Plots not included (Insufficient Data)

TABLE 4.2.5-1

BIOLOGY CLASS 1 INDICATOR VARIABLES

VARIABLE	MICROCLIMATE STATIONS										U.S.G.S.		PICE-ANCE CREEK ROAD	TRAFFIC		
	BC01	BC02	BC03	BC04	BC05	BC06	BC07	BC08	BC09	BC13	WU07	WU61		CB	PCN	PCE
1. PRECIPITATION	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
2. SNOW DEPTH	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
3. TEMP MAX	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
4. TEMP MIN	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
5. PERIPHYTON BIOPRODUCTIVITY											M	M				
6. DEER ROAD COUNT													W			
7. DEER ROAD KILLS													W			
8. TRAFFIC COUNT														W	W	W

NOTES: Microclimate data are collected twice monthly (2M);
Periphyton bioproductivity collected monthly (M);
and Deer and Traffic are counted weekly (W).
CB - Traffic Count between Piceance Creek Road and C-b Tract.
PCN - Piceance Creek Road north of C-b turnoff.
PCE - Piceance Creek Road east of C-b turnoff.

TABLE 4.2.5-2

BIOLOGY CLASS 1 INDICATOR VARIABLE TIME-SERIES INDEX

VARIABLE	MICROCLIMATE STATIONS BC01	BC02	BC03	BC04	BC05	BC06	BC07	BC08	BC09	BC13	U.S.G.S. WU07	WU61	PICE-ANCE CREEK ROAD	TRAFFIC CB	PCN	PCE
1. PRECIPITATION 2. SNOW DEPTH **	B8.7.5-1	-2	-3	-4	-5	-6	-7	-8	-9	-10						
3. TEMP MAX 4. TEMP MIN **	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20						
5. PERIPHYTON BIOPRODUCTIVITY											B8.6.2-1*	-2*				
6. DEER ROAD COUNT													B8.2.2-1			
7. DEER ROAD KILLS													B8.2.3-1			
8. TRAFFIC COUNT															B8.2.3-2*	

NOTES: * = Plots not included (Insufficient Data)
** = Combined

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5.0 HYDROLOGY

5.1 Introduction and Scope

A development monitoring program has been implemented to provide water quantity and quality data for the purpose of impact evaluation. Presently, streams, springs, seeps, and alluvial and bedrock aquifers are monitored. The program will be expanded to include monitoring of water associated with shafts, impoundments, and shale piles as development proceeds. Data obtained during baseline and interim-monitoring studies established reference levels for use in comparative studies during development. Bedrock quantity and quality data presented in this report, which were gathered prior to subsurface development, may still be considered as representative of "baseline" conditions.

The present hydrologic monitoring network is conceptually the same as during the baseline period. However, the bedrock aquifer system underlying C-b Tract has been redefined. Observation wells were completed in accordance with the concept that the Tract is underlain by two aquifers separated by the Mahogany Zone. Pump spinner tests conducted after the baseline period indicated that highly stratified aquifers and aquitards more accurately characterize the aquifer system. The more complex aquifer-aquitard system is illustrated in Figure 5.1-1. For purposes of identification, these new subdivisions of the previous upper and lower aquifer system are as follows:

1) UPC_1 - Upper Parachute Creek #1: Approximate limits extend from the base of the Four Senators Zone to the base of the A-Groove;

2) UPC_2 - Upper Parachute Creek #2: Extends from the base of the Four Senators Zone to the base of the A-Groove;

3) LPC_3 - Lower Parachute Creek #3: Extends from 30 feet below the base of the A-Groove to the top of the R-5 Zone;

4) LPC_4 - Lower Parachute Creek #4: Extends from the middle of the R-5 Zone to the base of the L-4 Zone.

Bedrock observation wells are scheduled to be recompleted to reflect the new aquifer concept. All water level measurements and water quality data inthis report are representative of the present two-aquifer completions.

This section presents the hydrologic analyses performed on the data collected on the C-b Tract to date with emphasis on data collected since November, 1976. An attempt has been made to convert to metric units. However, some of the data and analyses are reported in English units at the request of the Area Oil Shale Supervisor Office Hydrologic Group. Complete conversion to metric units will be made in subsequent Annual Environmental Reports.

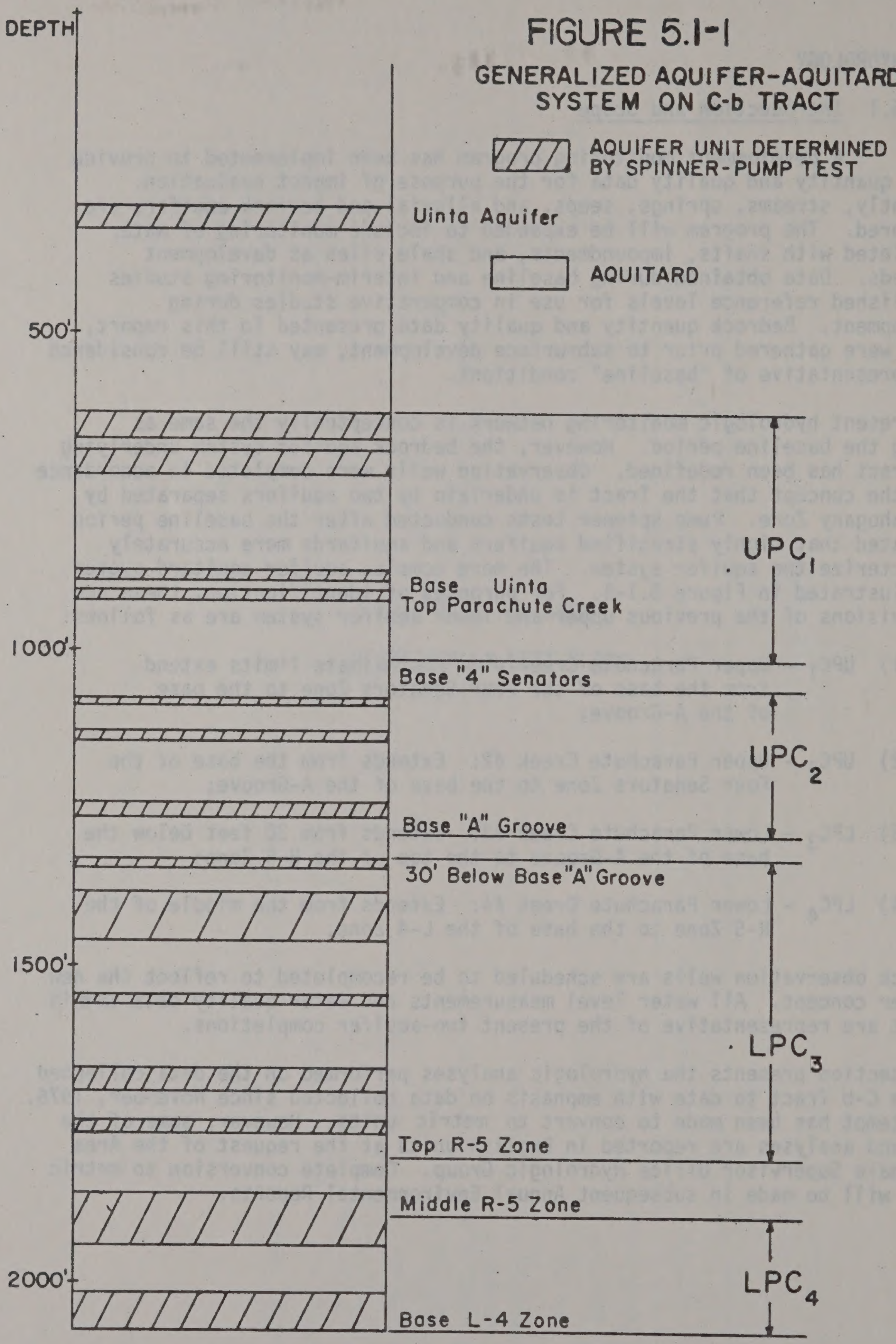


FIGURE 5.1-1
GENERALIZED AQUIFER-AQUITARD SYSTEM ON C-b TRACT

5.2 Surface Water Studies

Water quantity and quality data are collected at U.S.G.S. Gauging Stations on Piceance Creek and its tributaries in the C-b Tract vicinity in connection with an ongoing hydrologic monitoring program. The initial two years of the program obtained data relative to baseline conditions. A two-year study, although insufficient to identify trends in stream flow and water quality parameters, provided a preliminary basis for estimating their variability so that changes could be recognized and assessed.

Baseline studies indicated the mean flow for the reach of Piceance Creek adjacent to the Tract to be approximately fifteen cfs. These studies showed the water of Piceance Creek to be hard to very hard with $CaCO_3$ concentrations greater than 300 mg/l. The water was found to be a sodium-calcium-magnesium-bicarbonate-sulfate type.

Data gathered since the end of the baseline period have been used to analyze the mean annual flows, annual peak flows, and annual flow minimums of Piceance Creek. Water quality parameters were analyzed for time series trends and subjected to station-to-station comparisons.

5.2.1 U.S.G.S. Gauging Stations

5.2.1.1 Scope and Rationale

The surface water monitoring program is designed to detect unplanned point discharges, effluents from non-point discharges, and planned discharges from retention ponds. The major emphasis in surface water monitoring will involve non-point source pollution and direct discharges from storage reservoirs. Sources of these types include: (1) increased erosion rates and sediment loads due to construction activities, (2) runoff from process plant and paved areas, (3) runoff carrying solids resulting from air-borne particulate of gaseous emissions, (4) seepage or runoff from shale piles, and (5) infiltration into the groundwater system from reservoirs, ponds, or injection wells, and subsequent discharge at the ground surface.

5.2.1.2 Objectives

The monitoring program has been implemented to detect any changes in water quantity or quality that might be attributable to Tract development. Analysis will be undertaken periodically to identify any significant trends or changes between stations relative to discharge and water quality parameters.

5.2.1.3 Experimental Design

Thirteen surface water gauging stations (Figure 5.2.1-1) were constructed on and in the vicinity of C-b Tract by the U. S. Geological Survey in cooperation with the Colorado River Water Conservation District. The gauging stations constitute the surface water monitoring network, which has been in operation since the beginning of the baseline period.

Nine of the stations are located on ephemeral streams. Stations 007, 061, 022, and 058, which are located on perennial drainages and considered major gauging stations, are given as follows:

U.S.G.S. STREAM GAUGING STATION MONITORING NETWORK

FIG. 5.2.1-1

STATION CODE	USGS NUMBER	STATION LOCATION
WU07	09306007	Piceance Creek below Rio Blanco
WU61	09306061	Piceance Creek at Hunter Creek
WU22	09306022	Stewart Gulch
WU58	09306058	Willow Creek

For purposes of analysis, data were drawn from an additional gauging station (not shown in Figure 5.2.1-1) which is approximately five miles downstream of station 061 on Piceance Creek below Ryan Gulch.

5.2.1.4 Results and Discussions

This section is divided into two main sub-sections: stream flow and water quality. Stream flow is further divided into studies of hydrographs, flood frequency analysis and minimal flow analysis. For each of these, methods of analysis and results and discussion are separately identified for clarity.

5.2.1.4.1 Stream Flow: Hydrographs

Methods of Analysis

Plots of daily streamflow are given for Stations WU07 and WU61 in Figures B5.2.1-37 and B5.2.1-38. The hydrographs show the seasonal influence of runoff, evapotranspiration, and irrigation diversions on the flow of Piceance Creek. Flow in Piceance Creek has two components: baseflow and seasonal flow. Baseflow consists of groundwater recharge from alluvial aquifers and perched aquifers in the bedrock. Seasonal flow is comprised of storm runoff and snowmelt. December and January records reflect baseflow conditions while major irrigation diversions occur during the period April through September. The months of February, March, October and November are characterized by variable flows as a function of runoff and off-season irrigation diversions.

Total and mean annual streamflows for Stations WU07 and WU61, as well as Stations WU22 and WU58 are given below (Table 5.2.1-1). Station WU22 monitors the tributary draining Stewart Gulch and Station WU58 gauges the flow of Willow Creek.

TABLE 5.2.1-1 TOTAL AND MEAN ANNUAL STREAM FLOW

Water Year	Sta. WU07		Sta. WU22		Sta. WU58		Sta. WU61	
	Total (ft^3)	Mean (cfs)	Total (ft^3)	Mean (cfs)	Total (ft^3)	Mean (cfs)	Total (ft^3)	Mean (cfs)
1975	4866	13.3	710	2.0	725	2.0	6624	18.1
1976	3653	10.0	674	1.8	865	2.4	6069	16.6
1977	1831	5.0	503	1.4	508	1.4	3604	9.9

Results and Discussion

Discharge totals and mean values recorded for the stations draining the two perennial tributaries of Piceance Creek in the Tract vicinity are strikingly similar. The similarity can be attributed to comparable drainage areas (D_A Willow Creek = 48.7 mi^2; D_A Stewart Gulch = 43.4 mi^2), bedrock, and vegetation. A comparison of mean flows for Station WU07 (upstream) and Station WU61 (downstream) indicates a five cfs gain in discharge between stations. Mean discharge values of the Stewart Gulch and Willow Creek tributaries suggest that 75% of the flow increase between the Piceance Creek stations is due to surface water contributions. Presumably 25% of the gain may be attributed to groundwater inflow.

5.2.1.4.2 Stream Flow: Flood Frequency Analysis

Methods of Analysis

Prediction of the magnitudes of peak discharges for given frequencies at a gauging station or the recurrence intervals of floods of selected magnitudes is facilitated by flood frequency analysis. The analysis entails fitting a probability distribution to a sample of floods gauged at a station.

Piceance Creek is monitored by one gauging station with records of adequate length to perform a flood frequency analysis. U.S.G.S. Station 09306200 on Piceance Creek below Ryan Gulch has been in operation since 1965. Where no flood records exist for a given site or where the brevity of record precludes analysis for station records, other stations in the area provide records which can be regionalized and applied to the prediction of floods. Regional flood frequency curves were derived for two stream gauging stations U.S.G.S. 09306007 and 09306061. Station WU07, on Piceance Creek below Rio Blanco, is upstream of tributaries which drain C-b Tract while Station WU61 is downstream, above the mouth of Hunter Creek.

After a minimum of ten years of record has been obtained for an individual station, flood frequency analysis may be performed and compared to the corresponding regional curve. Results obtained from the regional curve will be of the same order of magnitude as those derived from station data.

A flood frequency curve (Figure 5.2.1-2) was plotted using annual peak discharges for water years 1966-1977. The maximum instantaneous discharge of each year was ranked in order of decreasing discharge and the corresponding recurrence interval was determined. (Table 5.2.1-2.)

The recurrence interval equals $\frac{n+1}{m}$, where n is the number of years of record and m is the rank.

Errors are inherent in flood frequency analysis for single stations due to (1) the brevity of most records, (2) the characteristic variability of floods, and (3) the difficulty of fitting theoretical frequency distributions to the sample record. In Figure 5.2.1-2, confidence bands were determined by multiplying coefficients (Beard, 1962) for the 90% confidence level by the standard deviation of the sample (σ = 92.7). Products obtained were added or subtracted for various discharges of the curve to produce upper and lower confidence bands.

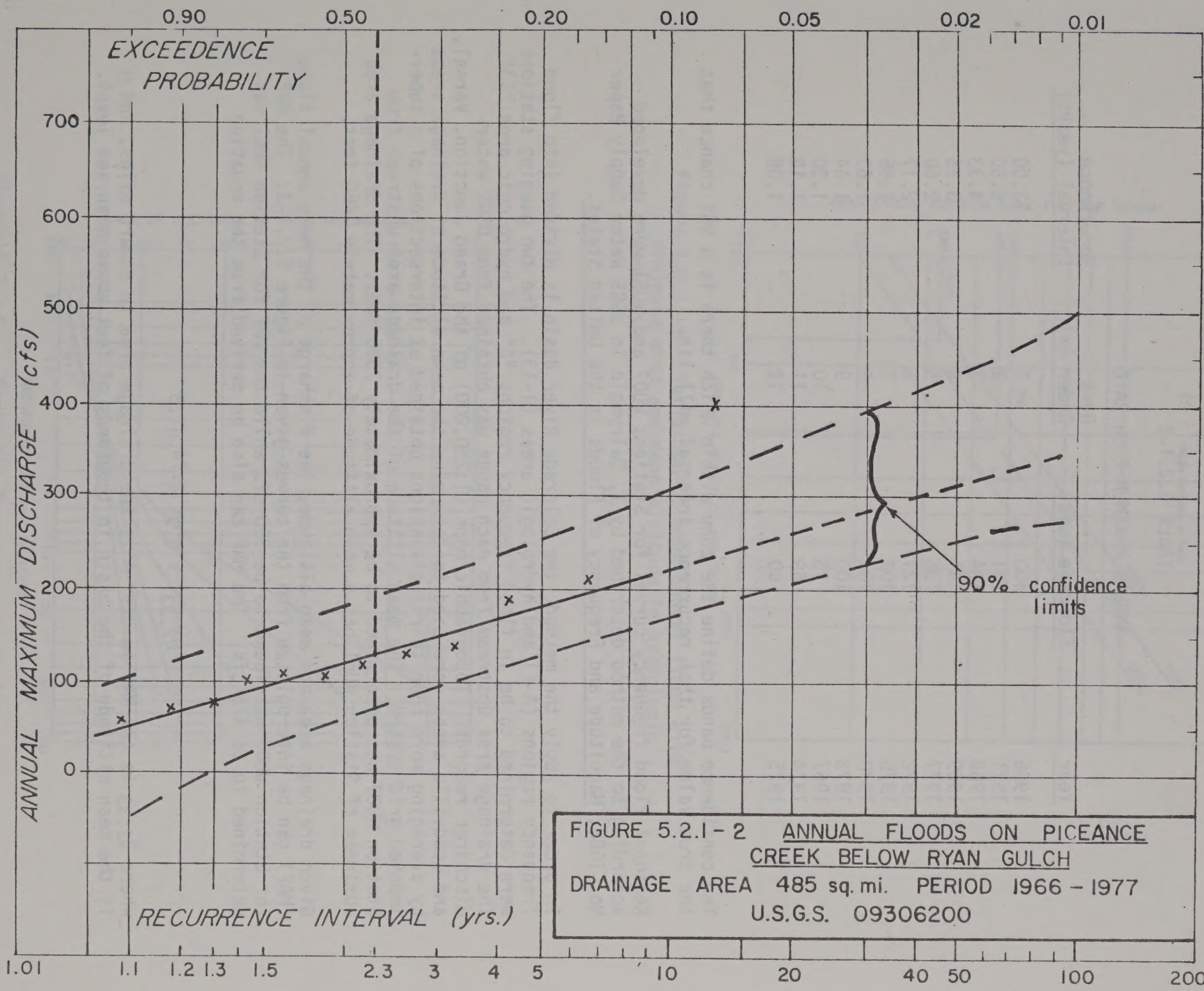


FIGURE 5.2.1-2 ANNUAL FLOODS ON PICEANCE CREEK BELOW RYAN GULCH
DRAINAGE AREA 485 sq. mi. PERIOD 1966 - 1977
U.S.G.S. 09306200

TABLE 5.2.1-2

ANNUAL MAXIMUM FLOW RATE

Year	Flowrate (cfs)	Rank Order (m)	Recurrence Interval (years)
1966	400	1	13.00
1971	211	2	6.50
1968	184	3	4.33
1969	141	4	3.25
1977	136	5	2.60
1972	121	6	2.17
1976	107	7	1.86
1970	104	8	1.63
1973	100	9	1.44
1967	75	10	1.30
1974	69	11	1.18
1975	60	12	1.08

The confidence bands define the zone within which there is a 90% chance that the true value for that recurrence interval will lie.

Regional flood frequency curves for Stations WU07 and WU61 were developed according to the method described by T. Dalrymple in USGS Water Supply Paper No. 1683, Magnitude and Frequency of Floods in the United States.

In order to apply the method, the Colorado River Basin is divided into flood frequency regions (A-F) and hydrologic areas (1-13). The two gauging stations were determined to be in flood frequency regions "C" and hydrologic area "13". The drainage area upstream from each gauge was obtained from USGS water-discharge records. Topographic maps (1:250,000) of the Grand Junction, Vernal, and Leadville areas were used to determine the mean altitude of drainage areas by averaging more than thirty elevations obtained at intersections of a super-imposed grid system. The mean altitude of the drainage area upstream from Station WU07 was determined to be approximately 7590 feet. The drainage area upstream of Station WU61 has a mean altitude of approximately 7460 feet.

Given drainage area and mean altitude, the discharge of the mean annual flood (MAF) can be interpolated from the curves given in Figure 5.2.1-3. The MAF for Station WU07 was found to be 330 cfs while the MAF for Station WU61 was determined to be 475 cfs. The MAF can also be derived from the equation

$$Q_{2.33} = 0.35\ A^{.74}\ H^{1.5}$$

Where $Q_{2.33}$ is the MAF in cfs, A is the drainage area in square miles, and H is the mean altitude of the basin in thousands of feet above mean sea level.

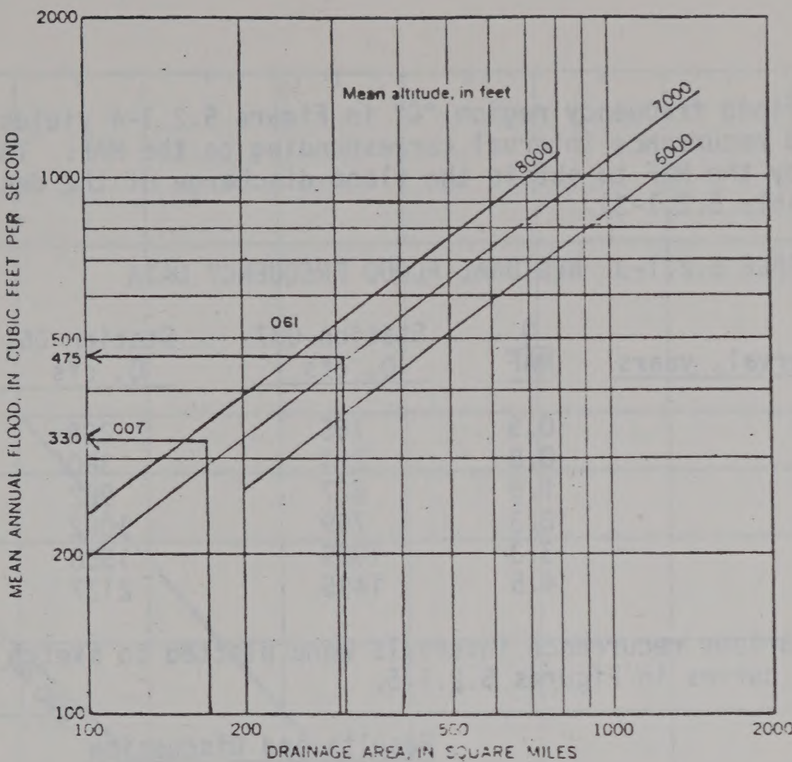


Figure 5.2.1 -3 - Variation of mean annual flood with drainage area and mean altitude in hydrologic area 13.

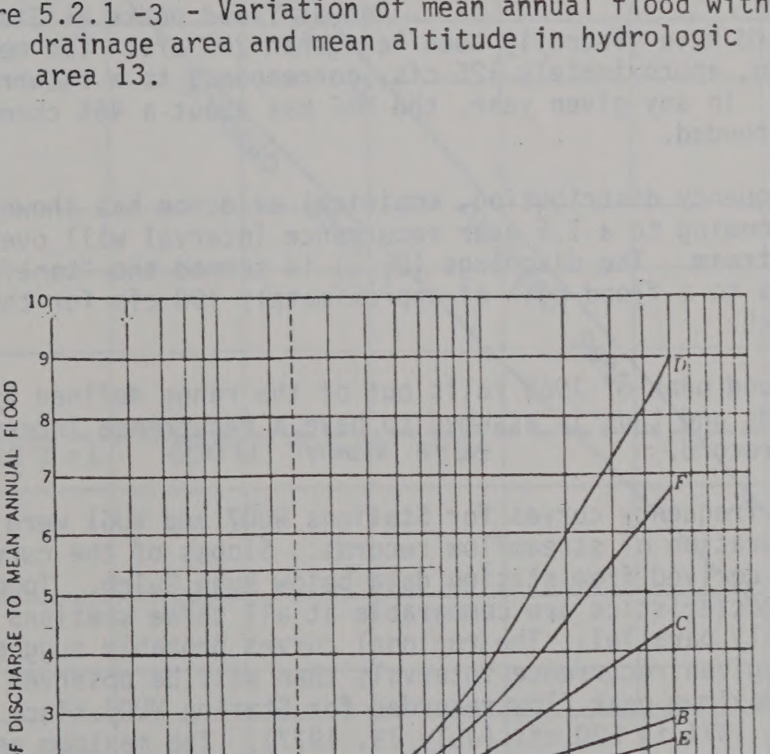


Figure 5.2.1-4 — Composite frequency curves for regions A-F.

The curve for flood frequency region "C" in Figure 5.2.1-4 yields the ratio of the selected recurrence interval corresponding to the MAF. The ratio $\frac{Q}{MAF}$, is multiplied by the MAF to obtain the flood discharge of the desired frequency. (Table 5.2.1-3)

TABLE 5.2.1-3 REGIONAL FLOOD FREQUENCY DATA

Recurrence Interval, years	$\frac{Q}{MAF}$	Station 007 Q, cfs	Station 061 Q, cfs
1.5	0.5	165	238
2	0.8	264	380
5	1.9	627	902
10	2.3	759	1092
20	3.3	1089	1568
50	4.5	1485	2137

Discharges of various recurrence intervals were plotted to sketch the regional flood frequency curves in Figures 5.2.1-5.

Results and Discussion

Annual flood peaks at Station 200 for the period of record have generally been less than 200 cfs. The mean annual flood for the station, approximately 125 cfs, corresponds to a recurrence interval of 2.33 years. In any given year, the MAF has about a 46% chance of being equalled or exceeded.

In a flood frequency distribution, empirical evidence has shown that the discharge corresponding to a 1.5 year recurrence interval will overflow the banks of any given stream. The discharge ($D_{1.5}$) is termed the "bankfull discharge" and corresponds to a flood peak of approximately 100 cfs for the station below Ryan Gulch.

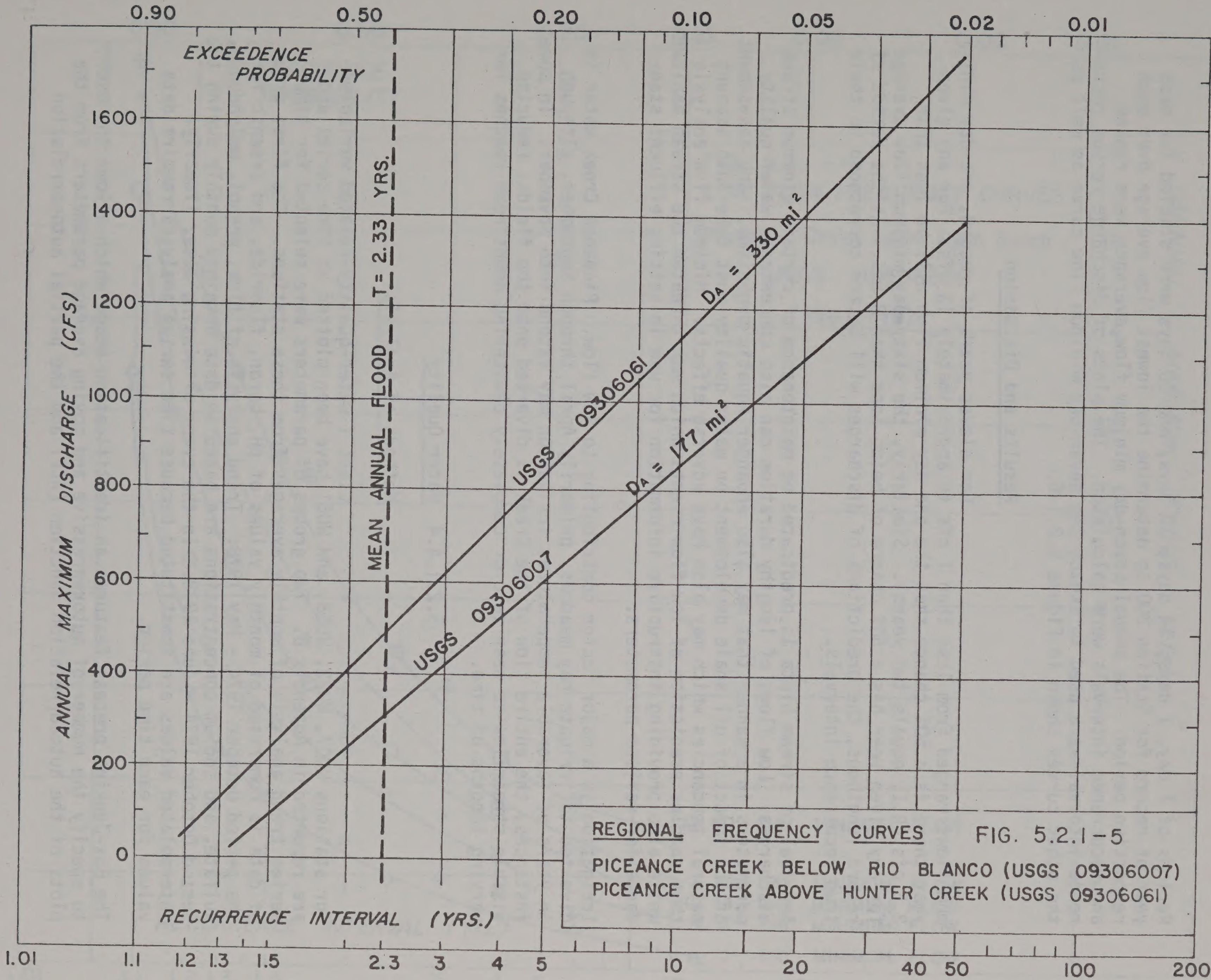
The 400 cfs flood peak of 1966 falls out of the range defined by the 90% confidence bands and thus is assumed to have a recurrence interval greater than the period of record.

Regional flood frequency curves for Stations WU07 and WU61 were obtained in view of the short duration of streamflow records. Slopes of the curves are greater than the slope derived from station data below Ryan Gulch. Topography and precipitation characteristics are comparable at all three stations and the curves should be roughly parallel. The regional curves probably suggest higher discharges for given recurrence intervals than will be observed in future station records. The maximum peak flow recorded for Station WU07 since the gauge became operational in 1974 is 520 cfs (July 19, 1977). The maximum peak flow at Station WU61 occurred September 3, 1977 and measures 492 cfs.

5.2.1.4.3 Stream Flow: Minimum Flow Analysis

Methods of Analysis

Extreme low flow at a station for periods of various lengths may be averaged and subjected to frequency analysis in the same manner as flood peaks.



REGIONAL FREQUENCY CURVES FIG. 5.2.1-5

PICEANCE CREEK BELOW RIO BLANCO (USGS 09306007)
PICEANCE CREEK ABOVE HUNTER CREEK (USGS 09306061)

Periods of 1 day, 7 days, 14 days, 30 days, and 60 days were studied for each year of record for Station 200 to determine the lowest flow average over each respective period. The annual seven-day minimum flow averages were ranked and recurrence intervals were calculated. The plots of discharge versus recurrence interval were used to sketch the seven-day minimum flow curve as well as the other curves shown in Figure 5.2.1-6.

Results and Discussion

For eleven years of record, one-day minimum flows ranged from less than 1 cfs to approximately 13 cfs. For any given year there is a 50% chance that the one-day minimum flow will be less than 2.5 cfs (R.I. equals two years). Similarly, the sixty-day minimum flow average for any given year has a 50% chance of being less than 8 cfs. As the period of record lengthens, the predictions of discharges will better correspond to their true recurrence intervals.

Survival of stream biota is predicated on maintenance of certain minimum stream discharges. Low flows of lengthy duration can also concentrate water quality parameters in a manner that may also endanger aquatic organisms. Any assessment of the impact of oil shale development on water quality must take into account natural tendencies which may also have adverse effects. Minimum flow analysis thus enables prediction of low flow events which may threaten the stream habitat while also providing instructive information for use in setting effluent standards for various parameters.

Irrigation is a major factor contributing to low flow. Piceance Creek water is diverted to irrigate hay meadows, primarily April through September, although in years of favorable temperatures irrigation may extend into November. In some instances, the entire flow of the Creek is diverted onto the fields, reducing visible streamflow to near zero or completely dewatering downstream reaches for varying lengths of time.

5.2.1.4.4 Water Quality

Methods of Analysis

Class 1 water-quality-related variables for stations WU07, WU22, WU58, and WU61 have been plotted as time series and are reported in Appendix B. Two groups of parameters were selected for time series trend analysis of monthly averages from these stations. The first group of data is comprised of monthly values of pH, boron, fluoride, and arsenic for the period October 1974 - May 1978. Trend analysis of flow, phenol, molybdenum, sulfate, and sodium concentrations are based on data obtained monthly during the period October 1974 - June 1978. In the event of missing data, linearly-interpolated values are substituted because time series analyses require data values for each time period.

The Box-Jenkins process features an identification stage which allows the user to specify the number of autoregressive and moving average parameters from the plots of the autocorrelation function (ACF) and the partial autocorrelation

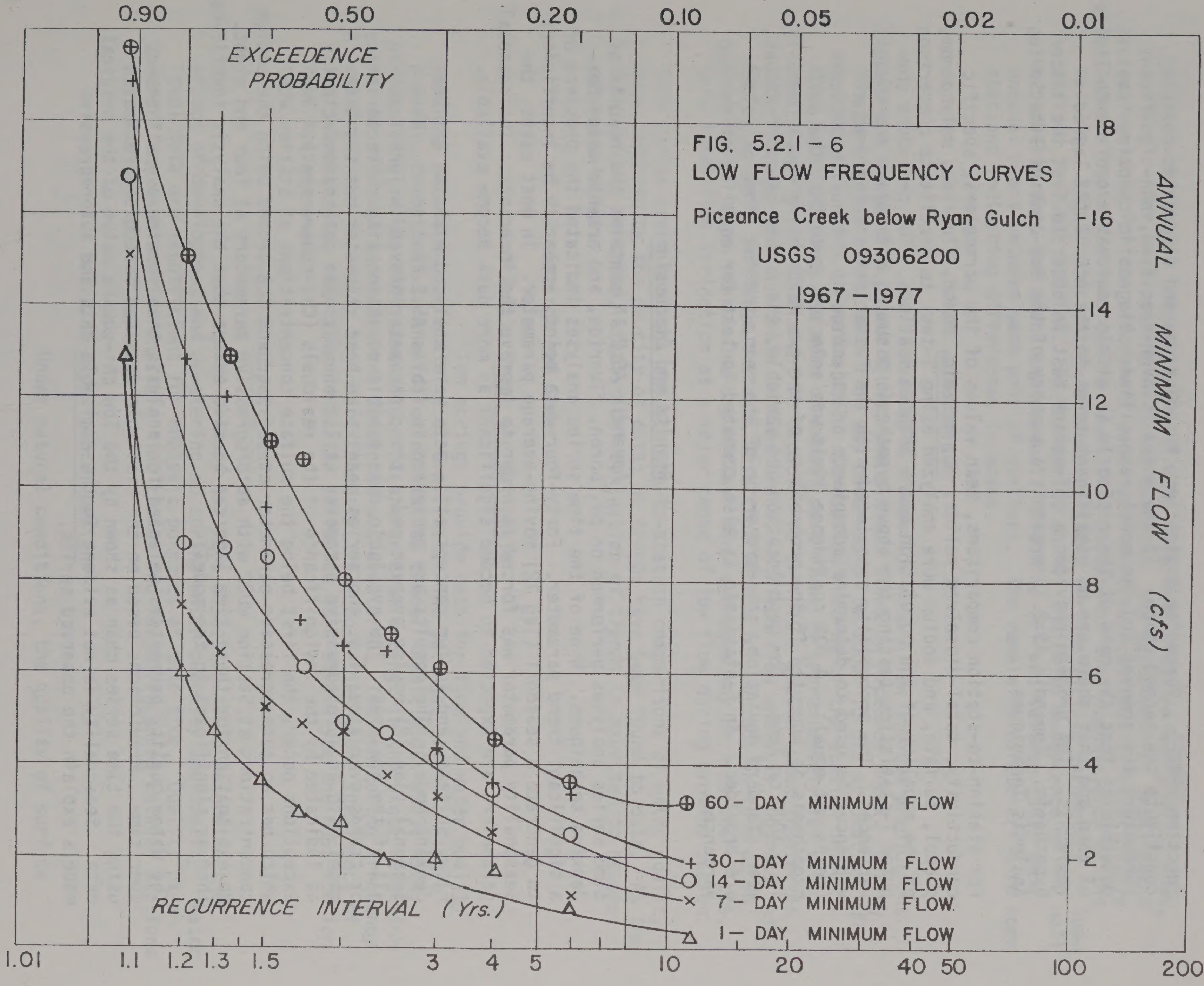


FIG. 5.2.1-6
LOW FLOW FREQUENCY CURVES
Piceance Creek below Ryan Gulch
USGS 09306200
1967-1977

function (PACF). Parameter estimation, forecasting, and diagnostic checking constitute the second stage. If the model is over-specified, non-significant parameters are removed and the model respecified. Diagnostic checking involves determining that the mean of the residuals is within reasonable confidence limits of zero and that there are no significant terms in the ACF of the lagged residuals. The program provides a chi-square test in order to test the latter hypothesis. Appendix A5.2.1D presents a summary of the Box-Jenkins Time Series Analysis Techniques.

For station-to-station comparisons, mean values of the parameters, specific conductivity, total dissolved solids, pH, arsenic, boron, fluoride, molybdenum, phenol, sulfate, and sodium were analyzed using T-test to facilitate comparison of the equality of the population means between stations. The procedure computes T-statistics testing the above hypothesis assuming both equal and unequal variances. The probability associated with the T-statistics using unequal variances is used to determine acceptance or rejection of the null hypothesis (means not equal). A 90% confidence limit was selected, such that the null hypothesis is accepted if the probability of the two means being equal (PROB>T) is 0.1000 or less. For each location and variable, the number of observations, mean standard deviation, standard error of the mean, and the range of values are provided. An F-statistic is also computed to test for equality of the two variances.

Results and Discussion

Appendix A5.2.1A contains the results of time series analyses performed on pH, boron, fluoride, and arsenic using Box-Jenkins techniques. None of the time series analyses indicated the presence of a significant trend parameter. Forty-four data points appear to be insufficient to generate a seasonal (lag 12) moving-average parameter. In most cases, the seasonality parameter was forced in order to improve the forecasts. The seasonal parameters are expected to become significant as more data become available.

Flow, sulfate, and sodium concentration data were analyzed with the OXY Box-Jenkins model. The results are presented in Tables A5.2.1A-1 to -3. Both a seasonal (lag 12) moving average and a trend parameter proved insignificant in all of the analyses. The available data exhibit no seasonality characteristics or trends over time; i.e. the series mean value best characterizes the data. A model with an autoregressive parameter at lag one fits the data satisfactorily as indicated by the insignificance of the residuals (Chi-square test). Two exceptions occur, the first being the sulfate concentrations at Station WU07 which has an autoregressive parameter at lag four and the second being the sodium concentrations at Station WU22 with autoregressive parameters at four and eight. No explanation for these time lags can be made except that the analysis identifies them as significant to the model.

The water quality parameters selected for analysis thus show no overall trends over time. Predictions based on the available data can best be approximated using the time series mean as shown by the low chi-square value of the original data. Seasonality is not evident in the available data and autoregressive models explain the observed series.

Station-to-station comparisons were made with USGS Stations WU07, WU22, WU58, and WU61. For each pairing of these stations, the acceptance of equal means was variable for the parameters examined. No clear-cut spatial relationship between these stations can be identified because of the inconsistency of the results. Significant change between stations for the various parameters is summarized in Table 5.2.1-4. In the table, an "A" indicates acceptance of the null hypothesis that the means are unequal. Fluoride (F) and sulfate (SO4) show unequal means between each pair of stations. The remaining parameters have some stations indicating differences in means.

5.2.1.5 Conclusions

Available streamflow data allow limited predictions of mean annual flow, peak flows, and minimum flows on Piceance Creek. During the period of record, mean flow was observed to be about 10 cfs at Station WU07 and about 15 cfs at Station WU61. Streamflow records of the station below Ryan Gulch indicate the mean of annual peak flows is approximately 125 cfs. Stations WU61 and WU07 might be expected to exhibit a smaller mean insofar as they are upstream and drain smaller areas. Minimum flow analysis suggests that Piceance Creek discharge averages less than 20 cfs for periods as long as 60 days in any given year. One-day minimum flow averages may be less than 1 cfs. Reed identifies irrigation as a major cause of low flow during growing season.

Time series trend analyses and station-to-station comparisons of water quality were hampered by the paucity of data; no trends have been found to date. As the data base is enhanced, statistical evaluation of trends is expected to become more meaningful.

5.2.2 Springs and Seeps

5.2.2.1 Scope and Rationale

Ten springs provide data for flow and water quality analysis on and in the vicinity of C-b Tract. The springs, shown in Figure 5.2.2-1, correspond to the following station codes: WS01, WS02, WS03, WS04, WS06, WS07, WS08, WS09, and WS10. Discharge from springs in the Uinta Formation may be affected as shafts are developed and dewatered. The monitoring frequency was increased to weekly beginning February, 1979 to better gauge the impact of shaft dewatering. The same indicator variables used to analyze the USGS station data are examined.

5.2.2.2 Objectives

The primary analysis objective is to determine the effect of development and dewatering on spring water quantity and quality. Water level data are insufficient for analysis purposes at this time. Quality parameters are examined for possible time trends and for differences between stations over the development period.

5.2.2.3 Experimental Design

Under natural conditions, the quality of surface

Table 5.2.1-4

T-TEST PROCEDURE SUMMARY FOR BETWEEN-STATION COMPARISONS
OF WATER QUALITY PARAMETERS AT USGS STATIONS

Variables	Stations 6007-6022	Stations 6007-6058	Stations 6007-6061	Stations 6022-6061	Stations 6058-6061	Stations 6058-6022
pH	R	A	R	R	A	A
B	A	A	R	A	A	R
F	A	A	A	A	A	A
As	A	A	R	A	R	R
Mb	R	R	R	R	R	R
SO_4	A	A	A	A	A	A
Na	R	R	A	A	A	R
NH_3	A	R	R	A	A	R
Spec Cond	A	A	A	R	A	A
TDS	A	A	A	R	R	A

Note: Table entries indicate acceptance (A) or rejection (R) of null hypothesis.
Ho: The paired station means are not equal. (90% confidence limit)

FIG. 5.2.2 - 1 SPRINGS & SEEPS AROUND Cb TRACT

water in springs and seeps was changed slowly but perceptibly with time as was demonstrated by the baseline data. Rates of change are related to rates of flow, which are determined by hydro-geologic considerations. Some groundwater basins unaffected by man show annual fluctuations in quality produced by seasonal variations in precipitation, aquifer recharge, water table levels, and discharge rates. The influence of man and industrial development is often marked as an increase in the amplitude of annual variation in quality along with a progressive decrease in average quality. To observe this change, if it does occur, indicator variables are analyzed for time trends and differences between stations. Multiple correlations and linear regression between parameters are used to test the following hypothesis: 1) dewatering will not affect water quality and quantity of springs and seeps, and 2) construction has no affect on water quality.

5.2.2.4 Method of Analysis

A linear regression is performed on the periodic observations of the various water quality parameters.

The independent time variable, YRMO, includes year and month information with the value being incremented for each month of a particular year; e.g. 74.0 represents January 1974. In order to test the hypothesis that the slope of the linear regression line is zero, two parameters from the SAS General Linear Models (GLM) procedure are examined.

The first test is to compare the model's estimate of the slope with the corresponding standard error of the estimate. The T-statistic at a 95% confidence interval with the appropriate degrees of freedom is then obtained from T-statistic tables. A 95% probability exists such that the true value of the estimate lies in the range ($m \pm \sigma$) where M is the estimate of the slope and σ is the standard error of the estimate. The T-statistic varies for the number of degrees of freedom and is reflected in the range calculations.

The second parameter examined from the GLM procedure is the probability that the slope is not zero. The procedure calculates a T-value for H_0: Slope = 0, from which the probability of the slope having a value significantly different from zero can be obtained.

5.2.2.5 Results and Discussion

Trends Over Time

Trend analysis Tables A5.2.2A-1 through A5.2.2A-7 summarize the results of the statistical analyses of trends. The units for the analyses are milligrams/liter. The small number of observations are the result of the springs being dry for several months of the year. Significant trends identified by station are:

Location WS01 - Both pH and SO_4 values exhibited significant trends. Since the sulfate values are downward-trending, their significance is not of concern. An examination of the data shows that the upward trend in pH values is largely due to a value of 9.2, (abnormally high) recorded in December 1977. Since the previous observation was taken in October

1976, it is difficult to conclude if the high value was a result of steadily increasing pH values or an isolated, perhaps spurious value.

Location WS02 - All slopes were non-significant, except for sodium, Na, which shows a positive trend. However, again only five observations were taken and the last observation, which was substantially higher, precipitated the trend. Subsequent observations are therefore needed to find out if the higher values persist.

Location WS03 - Values for boron, sodium and molybdenum show negative trends, which are not critical and probably are a reflection of some high measurements taken in October 1974.

Location WS04 - Data were not analyzed because all parameters consisted of four or less observations.

Location WS06 - No significant trends are detected.

Location WS07 - No significant trends are detected.

Location WS08 - Data were not analyzed because all parameters consisted of four or less observations.

Location WS09 - Boron was the only parameter showing a negative trend responding to high values reported in Fall of 1974 and 1975.

Location WS10 - Substantially higher sulfate and arsenic readings in December 1977 and June 1978 display positive (upward) trends. Subsequent sulfate and arsenic analyses at this station will determine if this upward trend continues.

Trends Between Stations

Comparison of the Means-between-Stations, Table 5.2.2-1, summarizes the results of statistical hypothesis that mean values between stations are different.

5.2.2.6 Conclusions

The statistical analysis suggests water quality of springs has not significantly changed over the baseline and subsequent development period. A few isolated statistical trends can be satisfactorily explained by the paucity of data or by abnormally high or low values (which are probably spurious). As more data become available, the statistical reliability will improve with a resulting increase in confidence of the results.

5.3 Ground Water Studies

5.3.1 Alluvial Wells

5.3.1.1 Scope and Rationale

Data from alluvial wells corresponding to station

Table 5.2.2-1

T-test Procedure Summary for Between-station Comparisons of Springs and Seeps

Variables	Locations WS01-WS03	Locations WS01-WS06	Locations WS01-WS07	Locations WS03-WS06	Locations WS03-WS07	Locations WS06-WS07
pH	R	R	R	R	R	R
B	R	R	R	R	R	R
F	R	R	R	A	R	R
As	R	R	R	R	R	R
Mb	R	R	R	R	R	R
SO_4	R	R	R	R	R	R
Na	R	R	R	R	R	R
NH_3	R	R	R	R	R	R
Spec Cond	R	R	R	R	R	R
TDS	R	R	R	A	R	R

Note: Table entries indicate acceptance (A) or rejection (R) of null hypothesis
Ho: The paired station means are not equal. (90% conficence limit).

codes WA01-WA12 are analyzed to test for possible changes in water level and selected quality parameters. The indicator variables defined in Section 5.2.1 are selected for statistical analysis. Figure 5.3.1-1 shows the location of the alluvial wells, which monitor each drainage in the C-b Tract vicinity.

5.3.1.2 Objectives

Objectives of alluvial well data analysis are detections of (1) significant rise or fall in water levels in wells, which might be attributed to pond seepage or dewatering, and (2) water quality trends over time or changes between stations during development of the Tract.

5.3.1.3 Experimental Design and Data Analysis

In order to characterize changes in alluvial aquifers, monthly measurements of water level and semi-annual analyses of water quality are presently obtained. Possible effects of surface disturbance, construction, shale pile development, impoundments and dewatering will be evaluated through time-trend and correlation analyses of water quality and quantity parameters.

5.3.1.4 Method of Analysis

(a) Water levels

Monthly water level measurements for four selected alluvial wells (WA03, WA05, WA06, and WA08) were analyzed for time trends and for differences between level measurements using standard statistical null hypothesis tests.

Time series plots of the water level data are also presented and qualitatively interpreted.

(b) Water quality

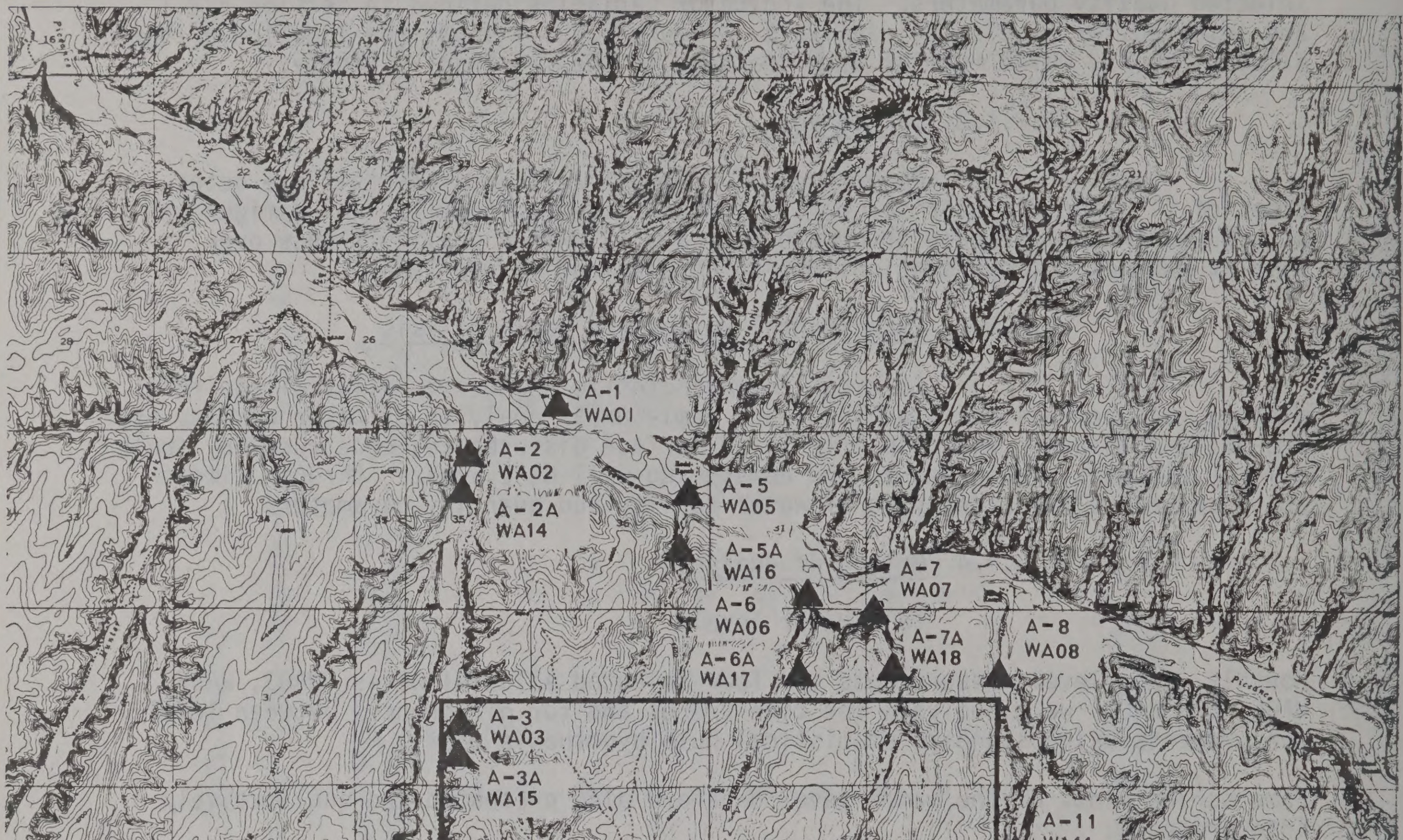
The statistical analysis of trends was accomplished by linear regression techniques which are described in Section 5.2.2.4. Parameter means between stations are compared by T-test for Class 1 indicator variables and stations only.

Frequency of data collection has varied from 0-3 observations per year. The irregularity and scarcity of data indicate that subjective evaluation of either abnormally high or low values should be made prior to drawing conclusions.

5.3.1.5 Results and Discussion

(a) Water levels

Time series plots of water level in four selected alluvial wells (WA03, WA05, WA06, and WA08) are presented in Appendix B as Figures B5.3.1-13, B5.3.1-14, B5.3.1-15, and B5.3.1-16. Qualitative interpretation of the figures indicates a possible trend toward lower water level in well WA03. The data suggest an annual cycle with highest water levels occurring in July and lowest water levels occurring in April. WA05, however, remained relatively constant across all months. Year 1977 shows lowest annual average level possible reflecting the low precipitation occurring that year.



ALLUVIAL AQUIFER MONITORING NETWORK WITH PROPOSED NEW ALLUVIAL WELLS A-2A, A-3A, A-5A, A-6A, A-7A

FIGURE 5.3.1.-1

Linear regression analysis was used to calculate the regression of water level with time. The hypothesis that the slope of the regression line is zero was tested for each of the same four wells. The hypothesis was accepted at the 5% level of significance for all wells indicating the samples statistically could have been taken from wells with no time trend. Results are shown in Appendix Table A5.3.1A-12.

Comparison of the mean water levels in the four wells resulted in rejecting hypotheses of equal water levels in paired comparisons except for wells WA05 and WA06 which accepted the hypothesis. Tests were made at the 5% level of significance.

(b) Trend Analyses

The results of trend analyses are tabulated for each well in Appendix Tables A5.3.1A-1 - A5.3.1A-11. Units are milligrams per liter. A brief summary is presented below:

<u>Station WA01</u> - No significant trends were detected for any of the indicator variables except for sulfate (SO_4) concentration. However, the trend is not critical because it is negative and does not reflect higher concentrations with time. An examination of the data shows that the SO_4 concentrations were relatively constant over the baseline period (1976), but dropped sharply in a March 1978 measurement. The low measurement, coupled with a relatively high value in October 1974, precipitated the statistical trend.

<u>Station WA02</u> - No significant trends were detected. The small number of observations of each parameter results in very wide confidence intervals, but the observations are evenly spaced such that no bias exists in the system.

<u>Station WA03</u> - Both fluoride and sodium concentrations exhibit significant trends which slope downward, indicating no contamination of the ground water. An abnormally high value for sodium was obtained in October 1974 which was approximately twice the value observed in subsequent measurements made in 1976 and 1978. The same is true for fluorine, which had a value of 1.90 in October 1974 and values approximately 0.40 in subsequent analyses.

<u>Station WA05</u> - The parameters showed no significant trends with time. A maximum of six observations were made.

<u>Station WA06</u> - The following parameters had slopes significantly different from zero: B, F, SO_4, Na. They are all negative slopes; thus no increase in parameter concentration is indicated. High parameter values recorded in October 1974 caused the trends to appear.

<u>Station WA07</u> - The analyses of B, F, and Na indicate a trend in a negative direction.

Station WA08 - No significant trends are detected.

Station WA09 - No significant trends are detected.

Station WA10 - The SO_4 concentrations show a negative trend. However, the molybdenum analyses show a positive trend. A very low value was recorded for molybdenum in October 1974 followed by more or less constant readings for the next four observations. The abnormally low value dictated the upward trend since there were only five observations. The data indicate that the resulting upward trend was not caused by consistently higher values with time. If the low value is considered spurious, then the remaining four observations do not constitute a trend.

Station WA11 - No significant trends are detected.

Station WA12 - No significant trends are detected.

(c) Comparison of Station Means

Appendix Table A5.3.1A-12 summarizes the results of T-test comparisons of parameter means. The comparisons are limited to the four stations identified as Class 1 indicator variables in Section 4.2.1.

With few exceptions, the null hypothesis is rejected between alluvial well locations indicating no significant changes in mean values of water quality parameters. The means of all ten parameters are not significantly different between locations WA03-WA05 and WA05-WA08. Specific conductance displayed significantly different means between the following location pairs: WA03-WA06, WA03-WA08, WA06-WA05, WA06-WA08.

5.3.1.6 Conclusions

The statistical analysis of available water quality data shows no overall trends over the period extending from the baseline period to the early part of 1978. Conclusions reached through this type of analysis are tentative due to the low frequency of data collection and consequent paucity of data.

Comparison of means between stations showed no significant differences for most comparisons. The notable exception is for specific conductance, which showed differences in four of the six comparisons.

5.3.2 Upper Aquifer (UPC_1, UPC_2) and Lower Aquifer (LPC_3, LPC_4)

5.3.2.1 Scope and Rationale

Data from gross water-bearing intervals above and below the Mahogany Zone were reviewed to assess changes in water level as well as water quality at various depths over time.

5.3.2.2 Objectives

Water level characteristics of aquifers above and below the Mahogany Zone will be compared to levels obtained after the onset of dewatering operations initiated in early 1979. Water level contour maps for 1976-1978 thus provide baseline information.

Water quality at the various depths over time is assessed for statistical significance for the following parameters: specific conductance, boron, aluminum, potassium, total dissolved solids, calcium, sodium, ammonia, and magnesium. The data presented are indicative of baseline conditions since subsurface activities (i.e. shaft-sinking) were not initiated until early 1979.

5.3.2.3 Experimental Design

Water level contour maps were generated for the two intervals to observe changes in head of the respective aquifers during the period November 1976 - November 1978. Well locations are given in Figure 5.3.2-1.

Five succeeding deeper intervals in the UPC_2 and the LPC_3 zones were analyzed for changes in water quality during the period 1976-1977. In the UPC_2 zone, analyses of water quality in succeedingly deeper open intervals in the well completions of SG-9-2, Cb-2, SG-11-3, AT-1C-3, and Cb-4 were used. Water quality parameters characteristic of AT-1C-1, which is open to the LPC_3 zone, were also analyzed.

5.3.2.4 Method of Analysis

(a) Water levels

Water level contour maps were generated on a monthly basis for the water-bearing zones above and below the Mahogany Zone. Contours are drawn at 50-foot intervals on base maps showing the C-b Tract boundary and well locations with corresponding water levels. A representative map of the Upper Aquifer is given in Figure 5.3.2-2. Additional plots are compiled in Appendix A5.3.2B. Plots for certain months are not given due to missing data or insufficient data to generate meaningful contours. Contour maps of lower aquifer water levels will be generated at a later date.

(b) Water quality

Analysis of variance was used in a 5 x 4 factorial design to assess the significance of depth and time on the selected water quality parameters. Originally, the data were organized in a factorial design matrix of the form 2 x 5 x 4 representing level classifications:

2. Aquifer depth levels (UPC_2 and LPC_3).

5. Graduated depth levels within the aquifer

4. Time Periods (1974, 1975, 1976, 1977).

DEEP WELL MONITORING NETWORK
C-b TRACT
FIG. 5.3.2-1

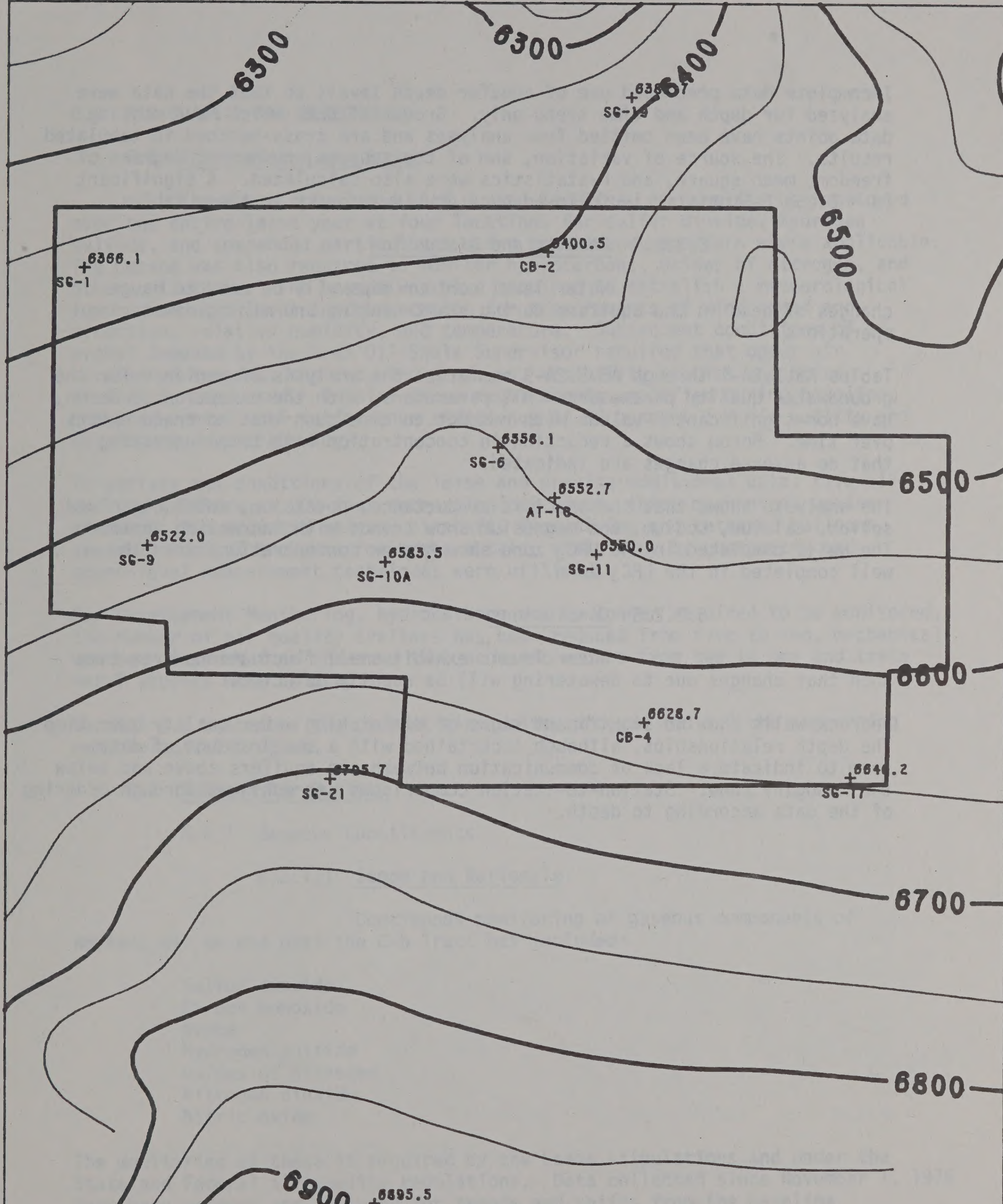


Figure 5.3.2-2 Potentiometric Surface Map - Upper Aquifer November 1976

Incomplete data precluded use of aquifer depth levels so that the data were analyzed for depth and time trend only. Groups of data which have missing data points have been omitted from analyses and are cross-hatched in tabulated results. The source of variation, sum of the squares, number of degrees of freedom, mean square, and F-statistics were also calculated. A significant ($\alpha = 0.05$) F-Statistic is followed by a double asterisk in these tables.

5.3.2.5 Results and Discussion

Water level contour maps will be used to gauge changes of head in the aquifers during shaft-sinking and mining dewatering operations.

Tables A5.3.2A-1 through A5.3.2A-9 summarize the analysis of variance for the groundwater quality parameters. All parameters, with the exception of boron, have non-significant F-values with respect to time such that no trend exists over time. Boron shows a reduction in concentration with time suggesting that no adverse changes are indicated.

The analysis shows that the specific conductance, potassium, total dissolved solids, calcium, sodium, and magnesium show trends with increasing depth. The wells completed in the UPC_2 zone show higher concentrations than the well completed in the LPC_3 zone.

5.3.2.6 Conclusions

Water levels exhibit small fluctuations over time such that changes due to dewatering will be readily detected.

Bedrock wells show no significant signs of diminishing water quality over time. The depth relationships, although ascertained with a small amount of data, seem to indicate a lack of communication between the aquifers above and below the Mahogany Zone. Station-to-station comparisons are achieved through ordering of the data according to depth.

6.0 AIR QUALITY AND METEOROLOGY

6.1 Introduction and Scope

The lease stipulated that, during Baseline, air quality be monitored over the entire lease year at four locations for sulfur dioxide, hydrogen sulfide, and suspended particulates using continuous recorders where applicable. The Lessee was also required to monitor hydrocarbons, oxides of nitrogen, and other pollutants. The Lessee was also required to establish a meteorological tower with multilevel instrumentation for measurements of wind speed and direction, relative humidity, and temperature. Subsequent conditions of approval imposed by the Area Oil Shale Supervisor required that upper air studies of temperatures and wind profiles, visibility studies and noise studies be conducted. Initial lease requirements, modified during baseline, required operational performance efficiency of 90 percent for air quality and 95 percent for meteorology.

To satisfy the conditions of the lease and provide additional data, five air quality trailers, a 200-foot meteorological tower, three mechanical weather stations, two acoustic radars, aircraft, free-flying and tethered balloons, special chemical analyses for trace metals, visibility by photometry and sound-level measurement techniques were utilized.

For Development Monitoring, hydrocarbons are no longer required to be monitored, the number of air quality trailers has been reduced from five to two, mechanical weather stations from three to two, acoustic radars from two to one and trace metal studies were deleted.

Section 6.2 describes the current air quality program and 6.3 the supporting meteorological program.

6.2 Ambient Air Quality

6.2.1 Gaseous Constituents

6.2.1.1 Scope and Rationale

Continuous monitoring of gaseous components of ambient air on and near the C-b Tract has included:

- Sulfur dioxide
- Carbon monoxide
- Ozone
- Hydrogen sulfide
- Oxides of nitrogen
- Nitrogen dioxide
- Nitric oxide

The monitoring of these is required by the Lease stipulations and under the State and Federal air quality regulations. Data collected since November 1, 1976 have been reduced and analyzed for trends and shifts from the baseline.

6.2.1.2 Objectives

The objectives of the analyses reported here are: a) to demonstrate compliance with applicable regulations; b) to examine potential long-term trends from baseline; c) to provide a general air quality status assessment; d) to identify potential sources of pollutants; e) to evaluate the significance of monitoring data.

6.2.1.3 Experimental Design

The air quality development monitoring network is shown in Figure 6.2.1-1. Environmental baseline data collection ended October 31, 1976. Starting with November 1, 1976 air quality and meteorological data have been collected continuously at the meteorological tower and air quality trailer site AB23 (formerly 023) located on the C-b Tract. Precipitation data have been taken continuously at Piceance Creek air quality trailer sites AB20 and AB23. Meteorological and air quality monitoring was resumed at this site (AB20) in February 1978. Also commencing in February 1978, two additional sites, AD42 and AD56, were activated to monitor particulates, wind speed, wind direction and ambient temperature. The data collected at each site, the frequency of collection and the start-up dates are shown in Tables 6.2.1-1 and 6.2.1-2.

A variety of factors can cause interruptions in continuous monitoring programs such as that undertaken at oil shale Tract C-b. In order to provide visibility to the usable data collected, data timelines are presented in Figures A6.2.1-1 through A6.2.1-4 showing by site, and parameter, the periods since November 1, 1976 for which usable data have been collected. Data collection has continued since September 1978; it is not yet reduced beyond that point.

Monitoring equipment in use has been subject to changes during the period of this report. During September 1978, having discontinued hydrocarbon monitoring, the Bendix gas chromatograph, which had been used for hydrocarbons and carbon monoxide, was retired. To continue monitoring of carbon monoxide, Beckman Model 866 non-dispersive infrared CO analyzers were installed in Stations AB20 and AB23. During March-July of 1977 an improved model of the sulfur gas analyzer previously used was installed in Station AB23 in parallel with the older unit. The new analyzer, a Meloy SA-185-2A has been in use since that time. In January 1978, Monitor Labs Model 8440E NO/NO_x monitors were installed in Stations AB20 and AB23, replacing the Meloy Model NA-520-2 analyzers previously in use. In each of the above changes, the new instrument is an EPA designated reference or equivalent method.

Specifications for all instruments are detailed in Table A6.2.1-1.

6.2.1.4 Results and Discussion

Results are grouped into separate studies and conclusions for each are drawn.

AMBIENT AIR QUALITY DEVELOPMENT MONITORING NETWORK

Note: ( )= Systems Dependent

FIGURE 6.2.1-1

TABLE 6.2.1-1

AMBIENT AIR-QUALITY & METEOROLOGY DATA DESCRIPTION

Symbols represent sampling frequency on Table 6.2.1-2

Category and Location	Start-up Date	SO_2	H_2S	Particulates (3)	Ozone	NO_x	NO	NO_2 (1)	CO	Horizontal Wind Speed	Horizontal (2) Wind Direction	Vertical (2) Wind Speed	Relative Humidity	Air Temperature	Precipitation (4)	Evaporation	Barometric Pressure	Solar Radiation	Temperature Difference	Mixing Height	Visible Range	Height	SF6
Air-Quality Trailer																							
020	a) Jan. '78			0						X	X				Z								
	b) July '78				X	X	X	X	Y					X									
	c) 1980	X	X																				
021	Systems Dependent																						
023	Nov. '74	X	X	0	X	X	X	X	Y						Z	S	X	X					
024	a) 1980			0						X	X			X									
	b) 1981	X	X																				
026	Systems Dependent																						
Weather Sta & Hi-Vol Sampler																							
042	Feb. '78			0						Z	Z			Z									
056	Feb. '78			0						Z	Z			Z									
Met. Tower @																							
3m	Nov. '74												X*										
10m	Nov. '74									X	X	X		X					2				
30m	Nov. '74									X	X			X									
60m	Nov. '74									X	X	X		X					2				
Upper Air Studies																							
Minisonde	Oct. '77									W	W			W								W	
Acous. Sound,020	Oct. '77																			U		U	
Visibility, Sta.060	Apr. '78																				V		
Tracer Studies	Fall '78																						T

* @ 1m

(1) $(NO_2) = (NO_x) - (NO)$
(2) Std. Deviation calculated.

(3) Also Size Distributions during Visibility Study

(4) These stations also used to obtain waterquality of ppt. measurements

TABLE 6.2.1-2

ABMIENT AIR QUALITY AND METEOROLOGY SAMPLING AND REPORTING FREQUENCIES

Symbols appear on Table 6.2.1-1

Symbol	Sampling Frequency	Minimum Average Time	Minimum Report Frequency	Description
X	10-seconds	5-minutes	1-hour	AQ & Low Alt. Meteorology
Y	5-minutes	5-minutes	1-hour	AQ & Low Alt. Meteorology
Z	Continuous	1-hour	1-hour	Precipitation
0	Every 3rd day	24-hours	24-hours every 3rd day	Particulates
2	20-seconds	5-minutes	1-hour	Temp. difference from 10-meter to 60-meter on Met. Tower
W	Approx. 30-seconds	Approx. 30-seconds	Approx. 30-seconds	Double Theodolite Minisonde
U	14-seconds		1-hour	Inversion Height/Mixing Layer from Acoustic Sounder
V	7 times per day every 6th day for 20 days in Spring and 20 days in Fall	Hourly	Daily (w/hourly max/min.)	Joint Visibility study with C-a from Hunter Creek Site
T	Continuous for approx. 2 days	1-hour	1-hour	SF_6 Tracer Studies for Air Diffusion Model Validation
S	Weekly	Weekly	Weekly	Evaporation

6.2.1.4.1 Data Uncertainty

Scope and Rationale

Much of the gaseous constituent data, with the exception of ozone, represent levels of concentration at or near the measurement threshold of the instrumentation. Data in this range must be interpreted with care due to several factors:

- Constant sources of error such as electronic noise and concentration fluctuations due to pressure and flow fluctuations in the instrument can represent a large percentage of the total output for low concentrations.

- It is generally not possible to calibrate ambient monitors at low concentrations with available calibration equipment.

- Each instrument is subject to a minimum detection level, below which the output can only be interpreted as noise.

In attempting to use such low-level data in correlative or predictive analysis, one must first determine the level of significance of the data as this will have a pronounced effect on the validity of any such analyses. This approach is indicated for the data on sulfur dioxide, hydrogen sulfide, nitrogen oxides, and carbon monoxide.

With respect to ozone, the measured concentrations have typically been well above the measurement threshold of the instrument. Nonetheless, there will be a degree of uncertainty attached to the ozone data which should be known and considered in relation to any data analysis.

Objectives

- To establish bounds of expected error for all gaseous monitoring data.

- To determine criteria of suitability for analysis for each data set.

Method of Analysis

A thorough analysis of data error requires primary information in three discrete areas:

1. Validity of the measurement method (e.g., Flame photometric detection for sulfur gases).

2. Precision of succesive measurements at a constant concentration, expressed as the standard deviation.

3. Accuracy obtainable with the measuring system.

The criterion of method validity rests on the theoretical basis of the method. In the case of ambient air monitors, the methods in use (especially those which are EPA reference or equivalent methods) are generally recognized through experience to be valid for the constituent in question.

The validity of the method is determined by establishing the appropriateness of the chemistry and physics of the analytical method. For instance, SO_2 analyzers using the flame photometric detector systems presume all SO_2 atoms will release the same quantum of energy (E) as a result of excitation by a hydrogen oxygen flame. The assumption is established by the accepted law $E=h_\eta$, where h=Planck's constant and η is frequency of the radiation; hence the validity of the method is determined. The question of equipment response is a different matter, that is for each h_η emitted, the photomultiplier does not necessarily produce a detectable signal. Therefore, the equipment response can be less sensitive than actual physics of the detector. Also, each atom of SO_2 may not reach an excited state thereby biasing the response on the low side. Difficulties with amplifier circuits receiving the photomultiplier output, and attenuating circuits, incrementing the output all contributed to produce a very complex systematic error in measuring h_η.

To establish data scatter, the calibration must be repeated numerous times in order to determine the precision of the analyzer. At least three values for each calibration point should be determined and their standard deviation calculated. The standard deviation is the most reliable index of random error. It should be pointed out that the standard deviation of the mean, δm, is reduced by successive measurements N, according to the relationship $\delta x/\sqrt{N}$. Therefore, it is not necessary to attempt to enhance the precision of each point by making a large number of determinations. If the standard deviation is large, then a review of the procedure would be more useful than making a large number of determinations.

The standard deviation of each series of measurements then represents the instrument's precision at that concentration. Part of the testing required for EPA certification involves this type of procedure. In the analysis presented in this report, manufacturers certified precision values were used due to a lack of information on actual measured precision.

Analyzer accuracy is determined by means of calibration. As applied to air monitors, this involves inputting calibration gas of a known accuracy and precision to the analyzer. The response of the analyzer is then compared to concentration of the standard gas. The resultant accuracy may be expressed as the percentage of the standard represented by the instrument output. The accuracy must be determined over the range of values encountered in ambient monitoring.

Once these basic areas have been analyzed, then the actual error analysis can proceed.

The objective of error analysis is to determine the degree of uncertainty of data from the measuring system, referenced to a specified degree of confidence. For example, a gaseous monitor result might be expressed as $50^{\pm}$ PPB (90%

confidence), meaning that there is a probability of .9 that the result lies between 45 and 55 PPB. Since trends in, and correlations between air quality parameters are often complex functions of many variables, it is desirable to determine the uncertainty in each variable to the maximum practicable confidence level. For this analysis, a confidence level of 95% has been chosen.

Then the problem simplifies to finding the expected standard deviation of system measurements over an appropriate range of concentrations. Assuming that all significant errors are random, then the variability of measurements at a single concentration will follow a normal frequency distribution. For this it follows that 95% of all measurements will be within two standard deviations (2δ) of the mean.

The mathematics of obtaining an overall system standard deviation as a function of component deviations is described in the Appendix in Table A6.2.1-2.

Results and Discussion

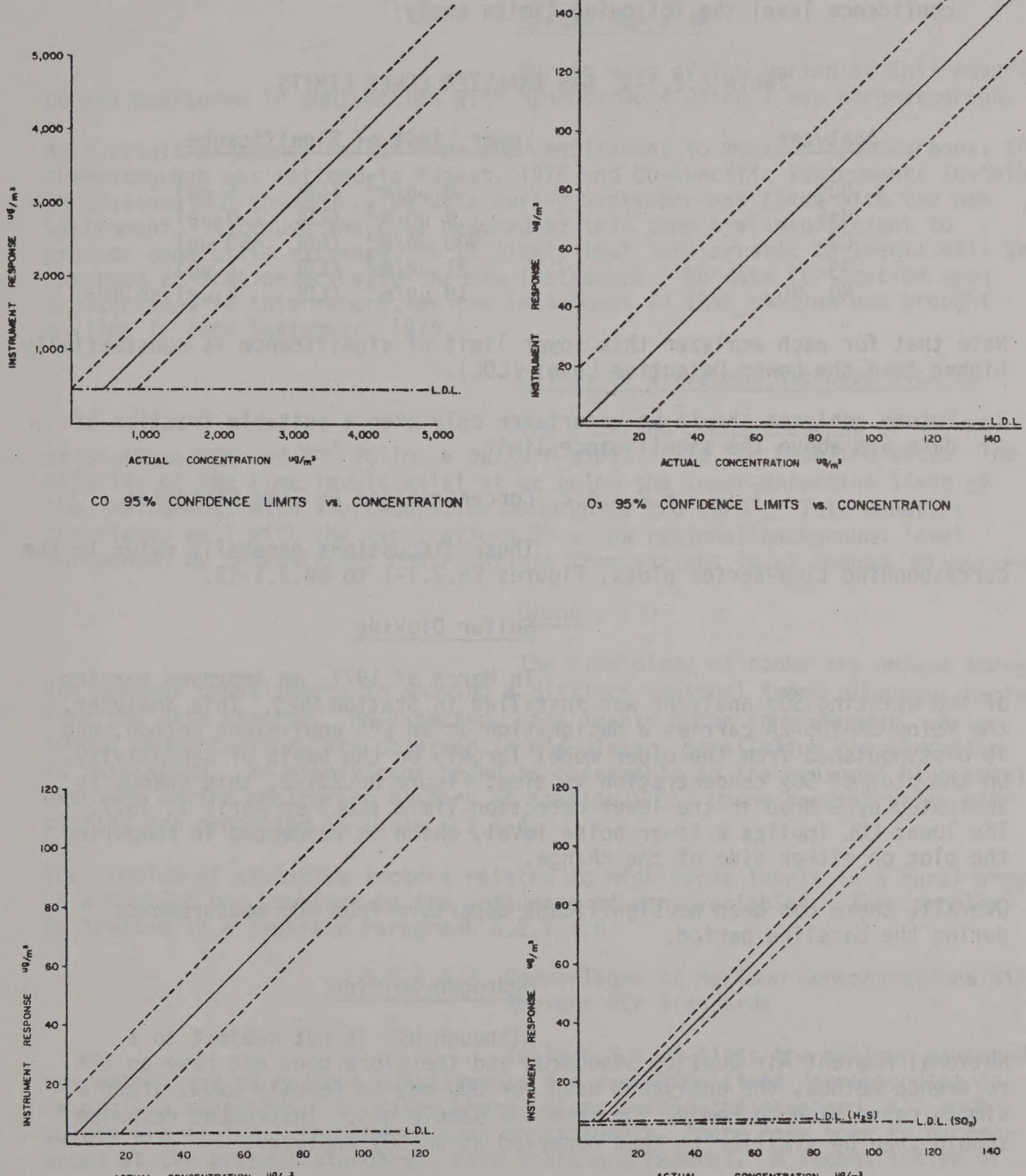
The results of this analysis as applied to each type of gaseous constituent monitor are presented in Figure 6.2.1-2. These plots represent the range of instrument response which would be observed for 95% confidence at a given concentration. The position of the plot relative to the axes is arbitrary, representing an "ideal" calibration. In actual practice, shifts in the slope and intercept of the calibration line might be observed. However, the relative magnitude of error at a given actual concentration would remain as shown.

The plot is not extended below the point where the lower confidence limit intersects the lower detection limit of the instrument. Instrument response below that point cannot be reliably assumed to represent a non-zero concentration.

The variation of expected error with concentration shows a similiar pattern for ozone, carbon monoxide, and nitrogen oxides. In each case, random error due to analyzer precision is dominant over error due to calibration precision. Analyzer precision is given as a fixed percentage of full scale, so it results in a level of error independent of concentration. For the sulfur cases, the error limits are seen to increase with concentration. This is due to the higher level of concentration-dependent calibration error, relative to analyzer precision. Input parameters used in the analysis are listed for each instrument in Table A6.2.1-1.

The results presented must be qualified to the extent that most of the inputs are manufacturer's specifications of performance data, which are directly applicable to the average analyzer of that type and model number. Each individual analyzer would, of course, be subject to some variation from this average. An effort is currently under way to obtain primary calibration and precision data for each analyzer, after which this analysis will be repeated.

FIG. 6.2.1-2 – MEASUREMENT ACCURACY OF AIR QUALITY PARAMETERS



CO 95% CONFIDENCE LIMITS vs. CONCENTRATION

O_3 95% CONFIDENCE LIMITS vs. CONCENTRATION

NO-NO_x 95% CONFIDENCE LIMITS vs. CONCENTRATION

SO_2-H_2S 95% CONFIDENCE LIMITS vs. CONCENTRATION

Conclusions

1. For each analyzer, there exists a response level below which indicated data are not significant at a given level of confidence. At the 95% confidence level the following limits apply:

Table 6.2.1-3 GAS ANALYZER LOWER LIMITS

Analyzer	Lower Limit of Significance
SO_2	8 $\mu g/m^3$ (LDL 5 μg)
H_2S	9 $\mu g/m^3$ (LDL 7.0 μg)
CO	900 $\mu g/m^3$ (LDL 450 μg)
O_3	21 $\mu g/m^3$ (LDL 1 μg)
NO, NO_x	19 $\mu g/m^3$ (LDL 4 μg) as NO_2

Note that for each analyzer this lower limit of significance is substantially higher than the Lower Detection Level (LDL).

2. Future analyses should be undertaken only when a suitable fraction of data are above the significance limit.

6.2.1.4.2 Concentrations As Time Histories

These discussions generally refer to the corresponding time-series plots, Figures B6.2.1-1 to B6.2.1-12.

Sulfur Dioxide

In March of 1977, an improved version of the existing SO_2 analyzer was installed in Station AB23. This analyzer, the Meloy SA-185-2A carries a designation as an EPA equivalent method, and is distinguished from the older model largely on the basis of sensitivity. On the plot of SO_2 concentration vs time, Figure B6.2.1-2, this change is indicated by a drop in the lower detection limit (LDL) on April 1, 1977. The lower LDL implies a lower noise level, which is evidenced in comparing the plot on either side of the change.

Overall, there has been no significant departure from SO_2 measurements during the baseline period.

Hydrogen Sulfide

Although H_2S is not subject to a National Ambient Air Quality Standard, and therefore does not have an EPA reference method, the analyzers used for SO_2 may be readily used, after a simple conversion to remove SO_2 from the sample gas. Instrument response should then be similiar to that observed as an SO_2 analyzer.

The levels measured during the period of this report contrast with the baseline levels in terms of lower apparent noise and lower peak values, both of which may be more indicative of improved instrumentation than any trend in background levels or source contributions.

Carbon Monoxide

During most of the period of this report, CO was monitored in conjunction with hydrocarbons using a gas chromatograph.

As a result of agency relief from the requirement to monitor hydrocarbons, the chromatograph was retired in August, 1978 and CO-specific instruments installed in Stations AB20 and AB23. The data during September was taken with the new instrument. Although the data reduced at this time are insufficient to provide conclusive evidence, it is likely that less erratic CO levels will be observed at Station AB23 with the new instrument. No data for Station AB20 are included in this report, as the instrument in that station was brought on-line in late September, 1978.

Oxides Of Nitrogen, Nitrogen Dioxide

The observed concentrations of NO_x-NO_2 at Stations AB20 and AB23 follow a pattern similiar to the baseline data. The majority of the time levels exist at or below the lower detection limit of the instrument, with short-duration peaks up to 150 $\mu g/m^3$. This behavior correlates well with the expectations of a low regional background level influenced by intermittent contributions from various local combustion sources.

Ozone

The time plots of ozone are unique among the gaseous constituents in showing a distinct seasonal trend distinguishable from the data scatter. As expected, peak levels occur in midsummer, while lowest concentrations are observed in mid-winter, paralleling the variation in insolation. No significant trend is observable in the seasonal high levels over the entire monitoring history at Station AB23. Ozone concentration statistics are presented in Table 6.2.1-4.

The problem of causative factors related to high ozone levels in a rural area is a complex one, subject to the influence of many variables. This problem is treated in a separate Paragraph 6.2.1.4.6.

6.2.1.4.3 Comparisons of Maximum Concentrations With Ambient Air Standards

Table 6.2.1.-5 lists the maximum measured concentrations of gaseous constituents for averaging times corresponding to respective standards. In cases where values exceed the standard, all such values are listed. For the gaseous constituents, there have been no exceedances at the present standards, both State and Federal. A recent action of

TABLE 6.2.1-4

OXIDENTS (O_3) AT STATION AB23

(1975 - 1977)

OXIDENTS (O_3)

FOR CALENDAR YEAR 1975

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 7160

Annual Arithmetic Mean (ug/m^3): 69.0

5-Highest Hourly Averages (ug/m^3):

	Value	Date	HOUR ENDING
1.	151.3	6/26	1400
2.	147.9	6/26	1500
3.	142.4	2/23	2300
4.	136.9	5/22	0300
5.	136.9	5/22	0400

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m^3)	3
3.0 - 20.9	39
21.0 - 40.9	1160
41.0 - 60.9	1752
61.0 - 80.9	1385
81.0 - 100.9	2205
101.0 - 120.9	530
121.0 - 140.9	83
141.0 - 160.0	3
GREATER THAN 160.0	0

OXIDENTS (O_3)

FOR CALENDAR YEAR 1976

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 8239

Annual Arithmetic Mean (ug/m^3): 62.0

5-Highest Hourly Averages (ug/m^3):

	Value	Date	HOUR ENDING
1.	124.0	4/26	1500
2.	123.0	4/26	1600
3.	122.4	4/26	1700
4.	120.3	4/26	1300
5.	119.3	4/26	1400

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m^3)	15
3.0 - 20.9	50
21.0 - 40.9	1197
41.0 - 60.9	2611
61.0 - 80.9	2890
81.0 - 100.9	1232
101.0 - 120.9	241
121.0 - 140.9	3
141.0 - 160.0	0
GREATER THAN 160.0	0

OXIDENTS (O_3)

FOR CALENDAR YEAR 1977

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 7874

Annual Arithmetic Mean (ug/m^3): 79.0

5-Highest Hourly Averages (ug/m^3):

	Value	Date	HOUR ENDING
1.	164.0	8/24	1100
2.	163.8	8/24	1200
3.	162.6	8/24	1400
4.	162.5	8/24	1000
5.	158.1	7/31	0900

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m^3)	2
3.0 - 20.9	4
21.0 - 40.9	105
41.0 - 60.9	1232
61.0 - 80.9	3405
81.0 - 100.9	2066
101.0 - 120.9	842
121.0 - 140.9	179
141.0 - 160.0	35
GREATER THAN 160.0	4

TABLE 6.2.1-5

COMPARISONS OF MAXIMUM BACKGROUND LEVELS WITH AMBIENT STANDARDS

APPLICABLE STANDARD	CONSTITUENT	AVERAGING TIME	STANDARD LIMIT ($\mu g/m^3$)	MAX. READING ($\mu g/m^3$)	DATA PRECISION ($\mu g/m^3$)	STATION WITH MAX. READING	DATE OF MAX. READING
COLORADO AMBIENT AIR QUALITY STANDARDS	PARTICULATES	ANNUAL	45*	14.5	0.6	023	1978
	PARTICULATES	24-HOUR	150**	178(1) 162(2)	11 10	024	11/27/74(1) 11/29/74(2)
	H_2S	1-HOUR	142	72.2	8	023	12/22/74
NATIONAL AMBIENT AIR QUALITY STANDARDS							
PRIMARY	SO_2	ANNUAL 24-HOUR	80 365	1.3 43.1	15 15	021 & 024 021	'74 - '75 6/16/75
SECONDARY	SO_2	3-HOUR	1300	87.7	15	023	12/21/74
PRIMARY	NO_2	ANNUAL	100	5.0	6	020	'75 - '76
PRIMARY	PARTICULATES	ANNUAL 24-HOUR	75*** 260	11.0 178	0.6 11	023 024	1978 11/27/74
SECONDARY	PARTICULATES	ANNUAL 24-HOUR	60*** 150	11.0 178(1) 162(2)	0.6 11 10	023 024	1978 11/27/74(1) 11/29/74(2)
PRIMARY	CO	8-HOUR 1-HOUR	10,000 40,000	4501.9 4650.9	100 100	020 020	6/03/75 6/04/75
PRIMARY	OXIDANT	1-HOUR	240	164.0(1) 163.8(2)	20 20	023 023	8/24/77(1) 8/24/77(2)

* Proposed change to 75 $\mu g/m^3$ under consideration

** Proposed change to 260 $\mu g/m^3$ under consideration

*** Geometric mean

(1) Highest max. reading

(2) Second highest max. reading

the EPA revised the ozone standard upward from 0.08 to 0.12 ppm. The two cases of hourly-average values in excess of the old standard are well below the current one.

6.2.1.4.4 Correlations With Wind Direction and Speed

Sulfur gases, nitrogen oxides and carbon monoxide

Concentration roses, depicting variations in concentration with wind speed and direction are presented in Figures A6.2.1-5 thru -9. For the sulfur and nitrogen gases as well as carbon monoxide, there is no detectable dependence of concentration on either wind speed or direction. This result is easily understood in terms of the low levels of these constituents, which are more representative of regional background levels than of any specific source contributions.

Ozone

Plots of ozone concentrations vs. wind speed and direction are presented in Figure 6.2.1-3. The data are presented in this form since the levels of concentration monitored are typically more significant than the other gaseous constituents. Over the period of time depicted on the plots, it is difficult to reach any conclusion regarding wind dependency. Again, this is characteristic of regional background levels, not influenced to any significant degree by specific sources.

6.2.1.4.5 Special Study: Side-By-Side SO_2 Measurements

Scope & Rationale

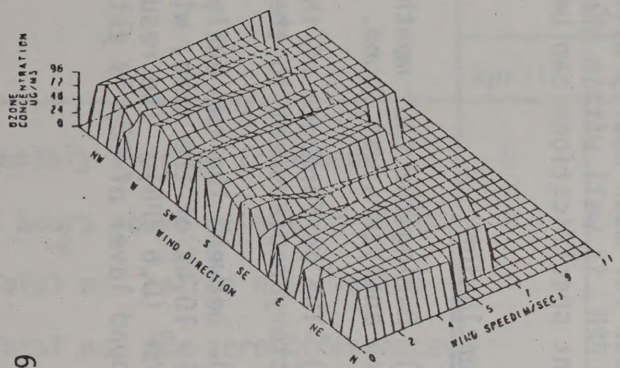
During the entire history of air monitoring at the C-b Tract, measured sulfur dioxide concentrations have averaged in the vicinity of the measurement threshold of the monitoring instruments, as shown in Figure B6.2.1-2. In order to validate the accuracy of the instruments in this range, and consequently qualify the resultant data, tests of co-located instruments have been made. Two tests were made: one over the period January through March, 1976 at Station AB21, and the other during April through July, 1977 at Station AB23. The earlier test was fully described in the Environmental Baseline Report.

Objectives

- to obtain a measure of agreement between co-located SO_2 analyzers
- to obtain an indication of the significance of air quality data for low concentrations of SO_2

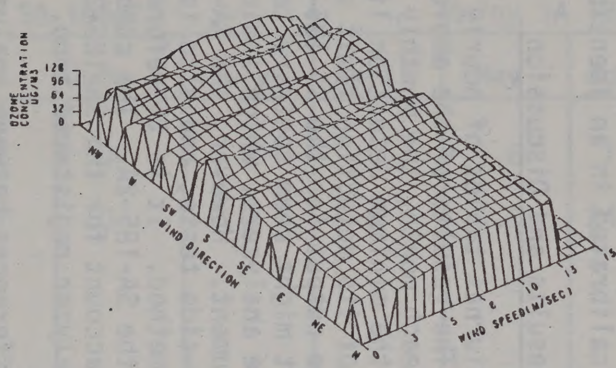
FIGURE 6.2.1-3

ONE HOUR OZONE CONCENTRATIONS AS FUNCTIONS OF WIND SPEED AND DIRECTION



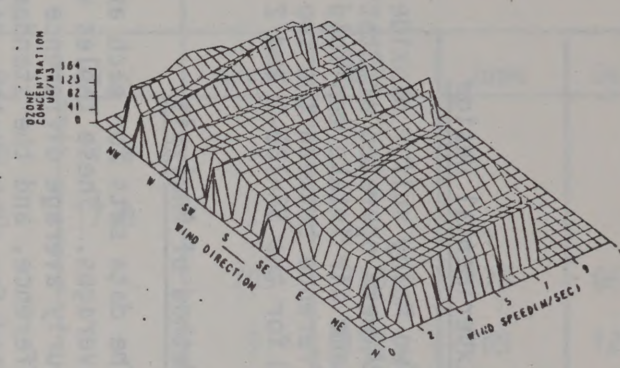
WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 DEC '76-FEB '77



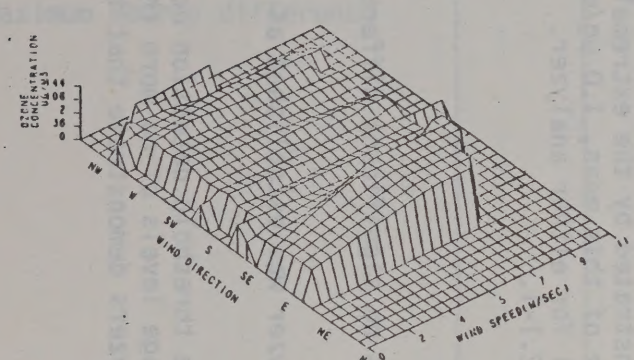
WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 MAR '77-MAY '77



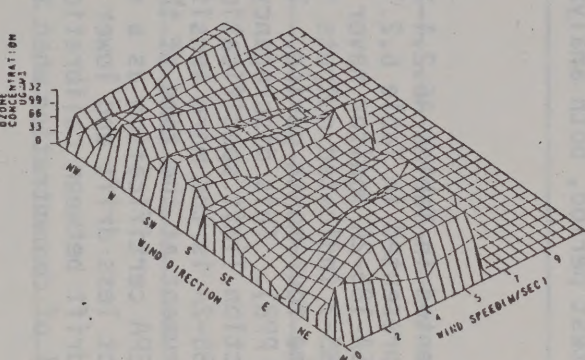
WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 JUNE '77-AUG '77



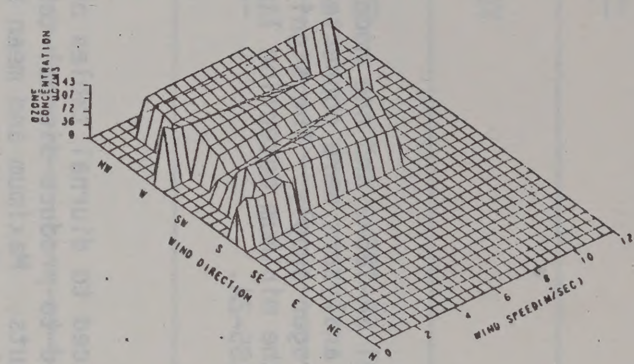
WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 SEPT '77-NOV '77



WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 DEC '77-FEB '78



WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 MAR '78-APR '78

Experimental Design

Two Meloy sulfur dioxide analyzers, one model SA-185-2 and one model SA-185-2A were operated at Station AB23. The two analyzers were connected to the same air intake manifold and the same hydrogen supply. The significant difference between the two analyzers is in the minimum detection limit: 5-PPB for the SA-185-2 and 2 PPB for the SA-185-2A.

Method of Analysis

The data sets for each analyzer were reduced to diurnal tables of hourly averages. These tables were then compared to produce diurnal tables of hourly average difference between analyzer outputs. Maximum and mean hourly difference, and the standard deviation of hourly average differences were computed for each month. Prior to and during the test period, both analyzers were calibrated in an identical manner.

Results and Discussion

Diurnal tables of hourly differences are presented in Tables A6.2.1-3a to d. The results of the above described analyses are presented in Table 6.2.1-6. For each month, the monthly average output of the SA-185-2A monitor never exceeded the minimum detection limit, while the SA-185-2 indicated outputs in excess of its detection limit an average of 10.6% of the four-month period. The average output for the SA-185-2 was 0.9 $\mu g/m^3$ (0.3 PPB). This discrepancy in output might seem contrary to the minimum detection limit specifications for the analyzers, which indicate that the SA-185-2A is the more sensitive instrument. However, the SA-185-2A was a new instrument at the time of the side-by-side tests, and also is made to qualify for EPA certification as a reference method. It is therefore reasonable to expect less drift and lower noise in the SA-185-2A. The combination of noise and drift between calibrations would account for the SA-185-2 indicating a low level of concentration when the new analyzer registered zero.

That most of the significant hourly differences between analyzers was random is demonstrated by the extremely low values for mean hourly difference. The maximum value of this mean, 1.0 $\mu g/m^3$ or 0.38 PPB, is well within the acceptable noise level for either analyzer. (Instrument specifications can be found in Table A.6.2.1-1.

Conclusions

1) During the four months of side-by-side tests no significant difference between analyzers was found.

2) The performance of the new SA-185-2A analyzer was established as a satisfactory replacement to the SA-185-2.

3) Between the two analyzers, outputs above threshold detection occurred only 10.6% of the time, with monthly average levels of no more than 1.6 $\mu g/m^3$ (0.6 PPB). The results for both analyzers demonstrate that the background level of SO_2 is extremely low.

TABLE 6.2.1-6 SUMMARY OF RESULTS OF SIDE-BY-SIDE SO_2 ANALYZER TEST ($\mu g/m^3$) 1977

Item	Analyzer								Difference Between Analyzers			
	#1 Meloy SA 185-2A				#2 Meloy SA 185-2							
	April	May	June	July	April	May	June	July	April	May	June	July
Monthly average (rounded)	0	0	0	0	0	1.6	1.0	1.0				
% hours above detection limit	0	0	0	0	0	1.0	24.5	17.0				
Total no. paired observation									709	736	676	662
Total no. non-zero differences									91	152	169	124
Mean hourly difference									0.3	0.5	1.0	0.47
Std. dev. of hourly difference									1.3	1.5	3.1	1.49
Maximum hourly difference									15	10	32	17

4) The standard deviation of the hourly differences for each month exceeds the corresponding monthly average by at least a factor of three, indicating that the actual analyzer output values are of little significance when measuring extremely low concentrations.

6.2.1.4.6 Special Study: Interrelationships of Ozone with Ambient Meteorological Parameters

Scope and Rationale

This is a study of the interrelationships of ozone with ambient air quality parameters. It is based on hourly averages of continuous measurements of ozone, solar radiation, temperature, relative humidity, barometric pressure, wind speed, and wind direction for the month of August, 1977.

Objective

To evaluate the interrelationships of several meteorological parameters on ozone concentrations in search of a weather-related explanation of significant shifts in diurnal ozone concentration levels.

Experimental Design

August, 1977 diurnal tables of hourly averages of continuous observations of ozone, solar radiation, temperature, relative humidity, barometric pressure, wind speed, and wind direction form this data base. Statistical analyses utilizing correlation, partical correlation, multiple regression, univariate time series, and multiple time series transfer functions were performed and evaluated comparatively. Time series analysis was used to develop forecast models with confidence intervals of ozone concentration. Forecasts of ozone concentration are compared with actual observations through periods of ozone-level shift.

Time series consisting of hourly values were plotted for each of the parameters. Ozone series was examined to identify time periods representing normal, low, transition, and high levels of concentrations. These periods were examined for interrelationships between ozone and meteorological parameters utilizing computer programs for correlation and multiple linear regression. Outputs of the computer programs provide analyses for evaluating statistical significance of interrelationships and value of these for predicting shifts in levels of concentration for ozone. (Bullard and Fosdick, 1979)

Results and Discussion

The primary data used for the study are the hourly measurements of ozone, solar radiation, temperature, relative humidity, barametric pressure, wind speed, and wind direction for the month of August 1977. Since these data were analyzed as time series, they are

presented here as a composite of computer plots of the individual diurnal series in Figure 6.2.1-4 with ozone in the center of the figure. The parameters were plotted by hour; days of the month are indicated. Vorticity data derived for the 500 mb pressure level were also used in the analysis and plotted as an overlay on the ozone plot.

Of interest in this study were shifts in the ozone level from a "normal" to "low" and then to "high", as indicated on Figure 6.2.1-5.

Day 23 was designated as "transition" day since the ozone level appeared to shift from the "low" to "high" level on that day. The "normal" period is extended through day 17 in later time series analyses.

The shifts between the levels of ozone as measured by the means and standard deviations were significant. Daytime highs and nighttime lows also shifted indicating that the diurnal patterns themselves completely shifted levels.

TABLE 6.2.1-7

SIMPLE CROSS CORRELATION MATRIX

		OZONE	SOLAR RADIATION	TEMP.	RH	PRESS	WS
OZONE	N	1.00					
	L	1.00					
	T	1.00					
	H	1.00					
SOLAR RADIATION	N	.52	1.00				
	L	.49	1.00				
	T	.37	1.00				
	H	.18	1.00				
TEMPERATURE	N	.80	.67	1.00			
	L	.86	.66	1.00			
	T	- .36	.66	1.00			
	H	.55	.69	1.00			
RELATIVE HUMIDITY	N	- .75	- .36	- .69	1.00		
	L	- .82	- .58	- .95	1.00		
	T	- .55	- .81	- .48	1.00		
	H	- .40	- .49	- .82	1.00		
BAROMETRIC PRESSURE	N	- .29	.13	- .31	.46	1.00	
	L	- .33	- .05	- .43	.53	1.00	
	T	.37	- .07	- .13	- .96	1.00	
	H	.52	- .22	- .05	.36	1.00	
WIND SPEED	N	.45	.37	.65	- .34	- .26	1.00
	L	.66	.67	.78	- .69	- .36	1.00
	T	-	.52	.86	- .70	- .13	1.00
	H	.11	.54	.55	- .62	- .65	1.00

NOTE: Normal, Low, Transition, and High ozone periods are designated by N, L, T, and H respectively. Correlation coefficients greater than .50 are significant at the .99 confidence level.

Coefficients of correlation were then examined to test the hypothesis that the interrelationships among the parameters remain unchanged for each of the ozone levels. Table 6.2.1-7 shows the matrix of the simple cross correlations without time lags. As might be expected, high correlation coefficients are indicated reflecting the significant diurnal effect on each of the parameters. Coefficients above 0.50 are significant at the 99 percent confidence level for the sample sizes.

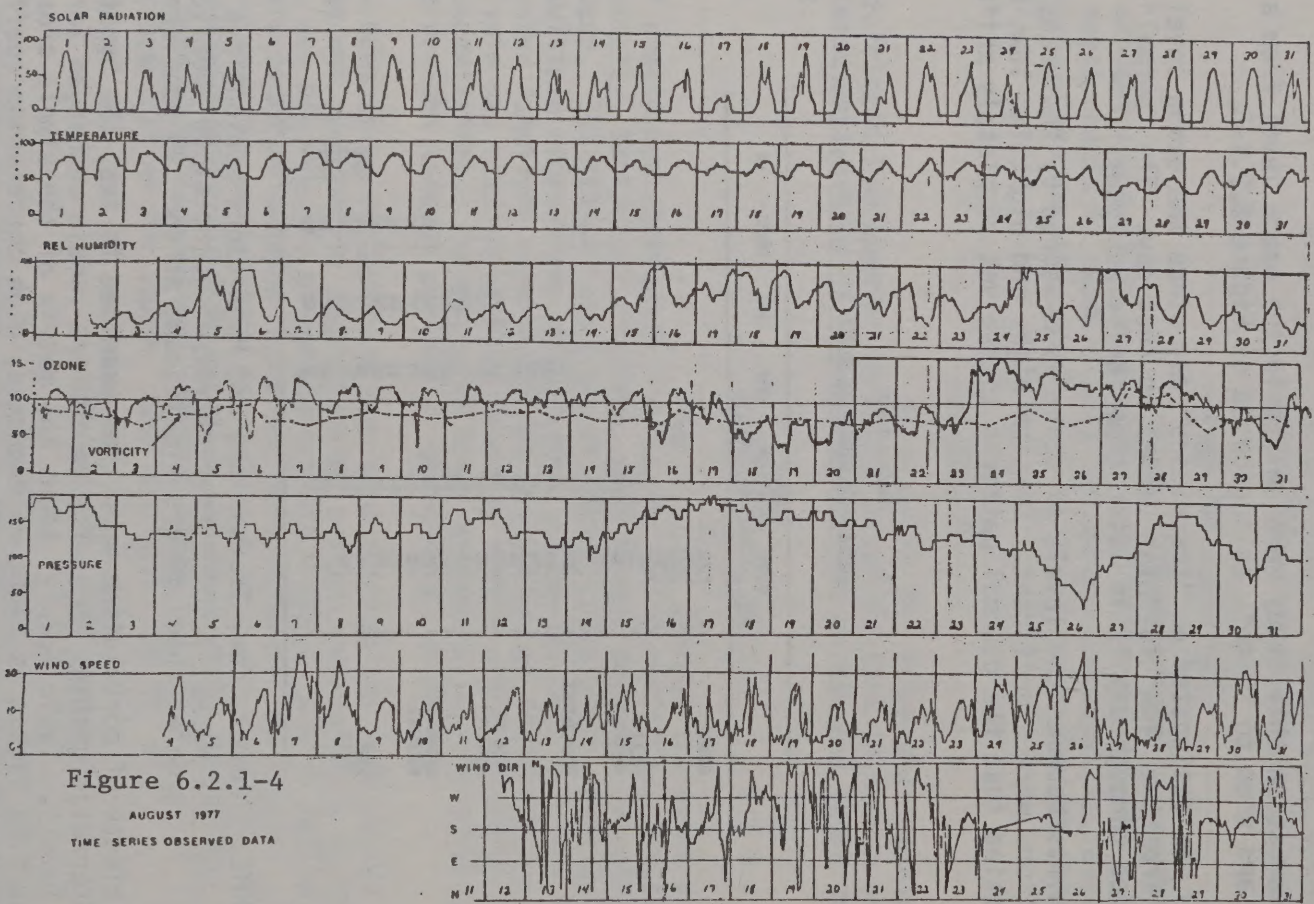
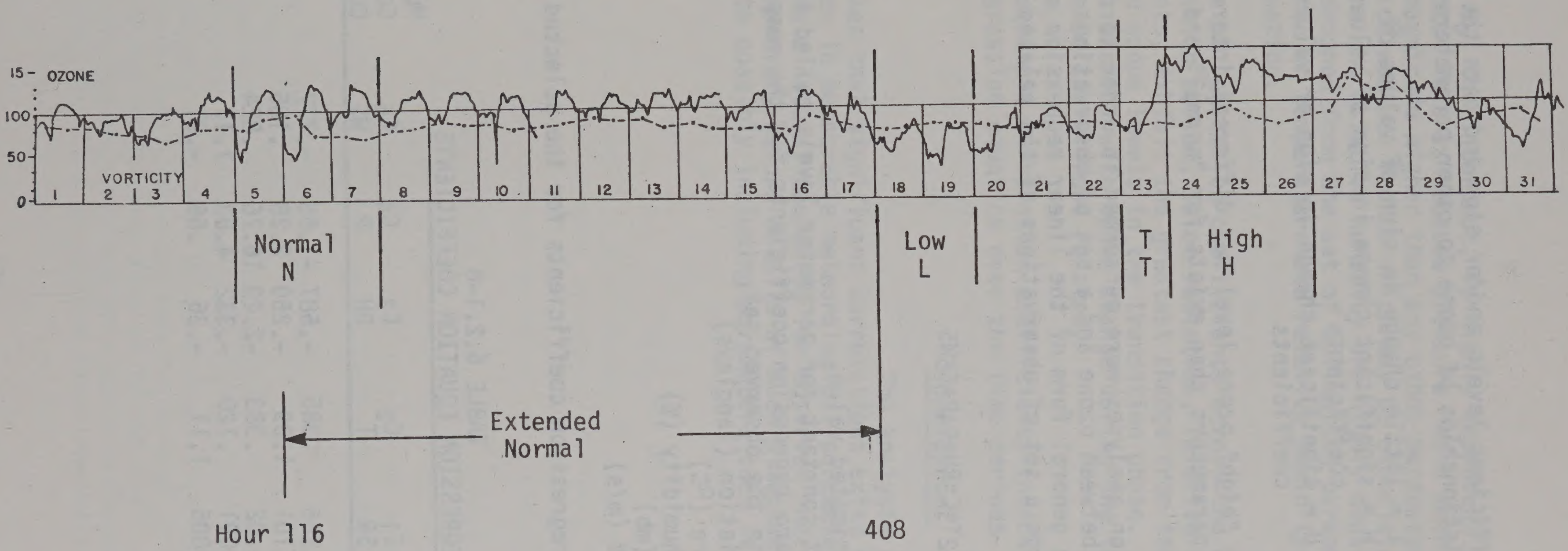


Figure 6.2.1-4

AUGUST 1977

TIME SERIES OBSERVED DATA

Figure 6.2.1-5 OZONE STUDY LEVELS AND ASSOCIATED STATISTICS



STATISTICS

Period	Ozone Level	Mean	Standard Deviation	Daytime High	Night-time Low	Significant Shift?
Aug 5-7	Normal	95.8	26.6	130 (ug/m^3)	43 (ug/m^3)	Ref. mean
Aug 18-19	Low	57.4	12.6	81	28	Yes
Aug 23	Transition	100.1	34.6	152	62	Yes
Aug 24-26	High	134.6	12.8	163	109	Yes
Aug 6-17	Ext. Norm.	96.1	18.3	129	31	---

Relative changes in coefficient levels and/or sign indicate the following with respect to interrelationships of ozone to other parameters:

between N and L = little change in sign of values of coefficients
between N and H = significant change in sign of values of all coefficients
between L and H = significant change in sign or values of all coefficients

Indications are that the "high" ozone level has different interrelationships with the meteorological parameters than exists for "normal" and "low" ozone levels.

Multiple linear regression analyses were performed in order to obtain the predictive relationship between ozone and a set of observations of meteorological parameters. The general form of the linear regression equation for estimating ozone (O_3) from a set of observations of the related parameters is:

$$\hat{O}_3 = B_o+C_1SR+C_2T+C_3RH+C_4P+C_5WS$$

where

$\hat{O}_3$ is ozone estimated value.
B_o is an offset constant for parameter levels called the intercept.
C_1, C_2, ...C_5 are regression coefficients for the respective parameters in the observed set.
SR = solar radiation (langleys)
T = temperature (^oC)
RH = relative humidity (%)
P = pressure (mb)
WS = wind speed (m/s)

Table 6.2.1-8 shows the regression coefficients for the selected ozone level periods:

TABLE 6.2.1-8
REGRESSION EQUATION COEFFICIENTS

Level	Bo Intercept	C_1 SR	C_2 T	C_3 RH	C_4 P	C_5 WS	Multiple Correlation Coefficient
Normal	- 964.8	.266	.385	-.587	-1.68	-.777	.97
Low	-1802	-.101	1.09	-.250	2.28	.185	.88
Transition	-13089	-1.02	.383	-2.29	16.76	.824	.93
High	-3679	-.091	.120	-.332	4.83	1.17	.89
Norm Est	-491.3	-.005	1.11	-.36	.66	-.91	.85

Note that B_o, the intercept, is highly dependent on C_4, the pressure coefficient. This is because pressure has a mean value of about 790 mb, order of magnitude higher than any other parameter. Pressure change is a precursor of weather fronts which may be associated with ozone shift. Temperature and relative humidity are highly negatively correlated and one could be dropped from the set of estimating parameters. However, the combined contribution of temperature and relative humidity are significant in the estimating equation.

Comparison of regression coefficients across the ozone levels show that, for the transition period, solar radiation, relative humidity, and pressure coefficients, exhibit the greatest change from their previous level. Pressure influenced ozone levels in the transition phase. The meteorological parameter interrelationships with ozone change during the transition period. This change appears to be storm front related.

The high multiple correlation coefficients indicate high predictive confidence in the regression equation over the time periods.

Conclusions

The analysis presented in this section demonstrates that significant correlations exist between shift in ozone levels and changes in measurable meteorological parameters. These correlations tend to indicate a natural mechanism for observed increases above background ozone levels. However, before details of such a mechanism may be elucidated, additional data possibly including parameters such as vorticity must be undertaken.

6.2.2 Particulates

6.2.2.1 Scope and Rationale

Monitoring of ambient particulates is required by the Oil Shale Lease Stipulations and by Federal and State Air Quality Regulations. Measurements were made on a daily basis through August 1977 and on an every-third day schedule at Station AB23 from September 1977 through September 1978 and continue on that basis. Additional particulate monitoring was initiated in February 1978 at Stations AB20, AD42, and AD56 on the same three-day sampling schedule. During visibility measurement days, size-distributed samples have been taken at Station AB23.

6.2.2.2 Objectives

- to demonstrate compliance with applicable regulations
- to examine potential long-term trends
- to provide a general air quality status assessment
- to identify potential particulate sources

6.2.2.3 Experimental Design

The EPA reference method for particulate monitoring, the hi-volume sampler, is employed at all stations to measure particulates. The samplers are located such that the air intakes are approximately 4.6 meters above ground level. An Anderson particle-sizing head is used in place of the standard filter assembly for size-distributed samples. As yet, there is no EPA reference method for particle size sampling.

6.2.2.4 Method of Analysis

The data on ambient particulates were not subjected to any formal analysis that resulted in usable information. Multiple regression analysis utilizing a technique and set of correlative parameters similar to those used in the visibility analysis failed to produce any valid correlations.

Three dimensional and time-series plots of particulate data provide a means of interpreting the data in a qualitative way. These are discussed in the following subsections.

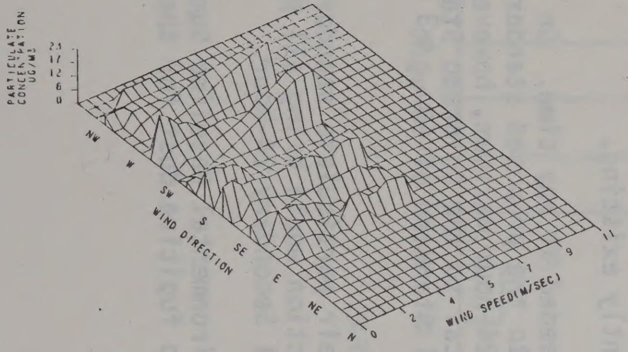
6.2.2.5 Results and Discussion

6.2.2.5.1 Correlation With Wind Direction and Speed

Plots of particulate concentration vs. wind speed and direction for Station AB23 are presented in Figure 6.2.2-1. In general, the data show a marked dependency on wind speed, as would be expected in a situation where particulate concentrations are primarily the result of fugitive sources. This factor is most evident during the spring and summer quarters. During the rest of a typical year, substantial periods of snow cover reduce the background level and change this relationship.

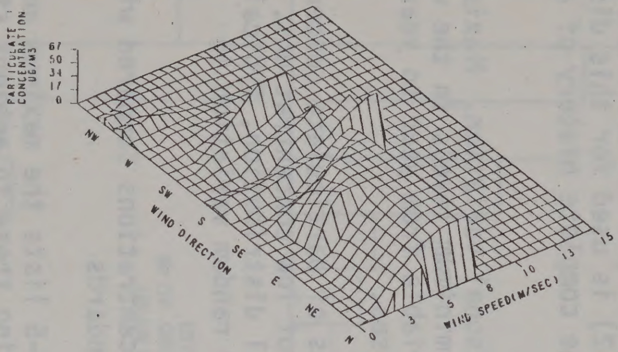
FIGURE 6.2.2-1

DAILY TOTAL PARTICULATE CONCENTRATIONS AS FUNCTIONS OF WIND SPEED AND DIRECTION



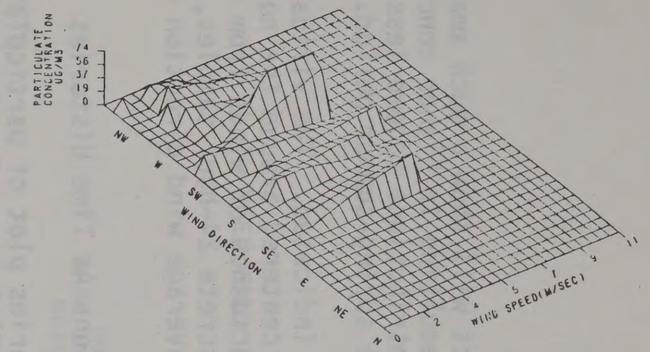
WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 DEC '76-FEB '77



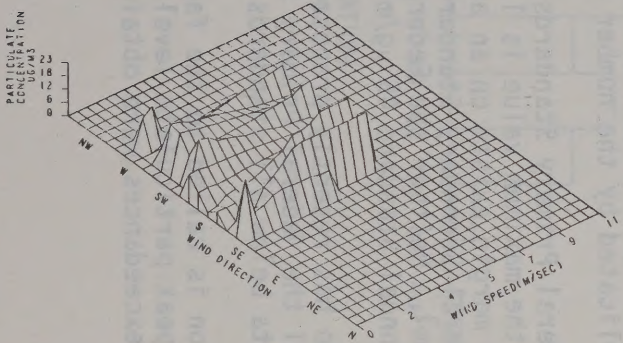
WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 MAR '77-MAY '77



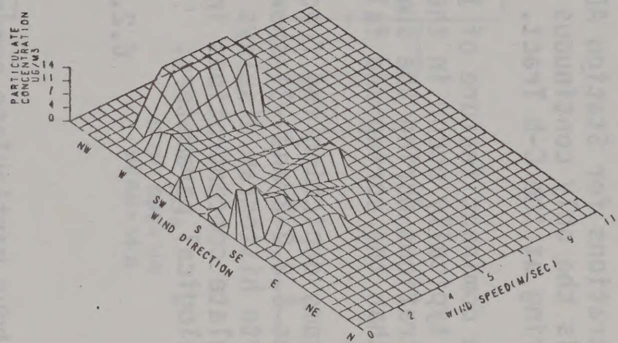
WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 JUNE '77-AUG '77



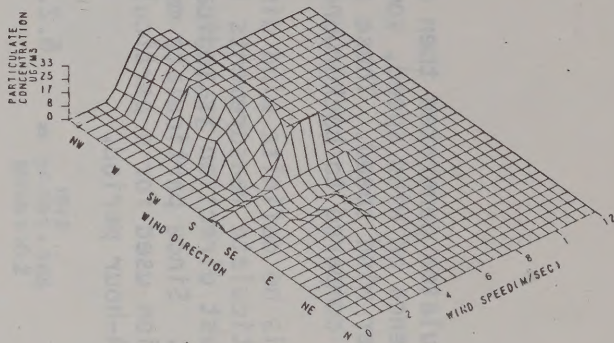
WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 SEPT '77-NOV '77



WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 DEC '77-FEB '78



WIND SPEED-DIRECTION VS CONCENTRATION

STATION AB23 MAR '78-MAY '78

Particulates generated then on or near the Tract will show a much smaller dependence on wind speed, sometimes actually resulting in higher concentrations at lower wind speed. These source-specific contributions become less significant compared to background levels during the spring-summer period.

There is no definite wind direction dependence indicated. The virtual absence of particulate measurements in the wind sector centered around the north-northeast direction is indicative of the low incidence of winds from that sector. Since particulate measurements are discrete 24-hour samples, the direction used for a particular sample is the average wind direction during that 24-hour period.

6.2.2.5.2 Concentrations As Time Histories

The time series plot of particulate concentrations for Station AB23 (Figure B6.2.2-2) is used for this discussion, as it is the only continuous record covering the complete history of air monitoring at the C-b Tract.

The one dominant feature of the plot is the seasonal variation. Maximum levels typically occur in the spring and fall, minimum levels in the winter. Concentrations during the summer months are variable from year to year, but are lower than the spring and fall peaks in most cases.

Histograms depicting the frequency distributions of particulate concentrations (Figures 6.2.2-2 and -3) show the predominance of low concentrations. The composite histogram displays a skewed log-normal distribution, typical of particulate concentrations influenced mainly by random variation in meteorological parameters.

6.2.2.5.3 Maximum Concentrations Compared with Ambient Standards

Table 6.2.1-5 lists the maximum annual and 24-hour particulate concentrations. Comparing these to ambient standards is complicated by the number of standards currently existing.

The Federal Primary Standards have not been exceeded at any time. On a 24-hour basis, the maximum value is 178 $\mu g/m^3$ compared to the proposed standard of 260. A wider margin exists on an annual basis. The 24-hour maximum, however, exceeds the Federal Secondary Standard, which is identical to the Colorado Standard, 150 $\mu g/m^3$. Neither the Federal Secondary Annual Standard of 60 $\mu g/m^3$ nor the State Annual Standard 45 $\mu g/m^3$ is approached.

Colorado has recently proposed a revision of their particulate standards to parallel the Federal Primary Standards. This action would bring all particulate data below all standards except the Federal Secondary 24-hour.

Attention is called to the fact that in the Environmental Baseline Summary Report peak particulate levels are attributed to fugitive dust for the time period exceedances were obtained.

FIGURE 6.2.2-2
FREQUENCY DISTRIBUTION OF PARTICULATE
MEASUREMENTS
BY YEAR

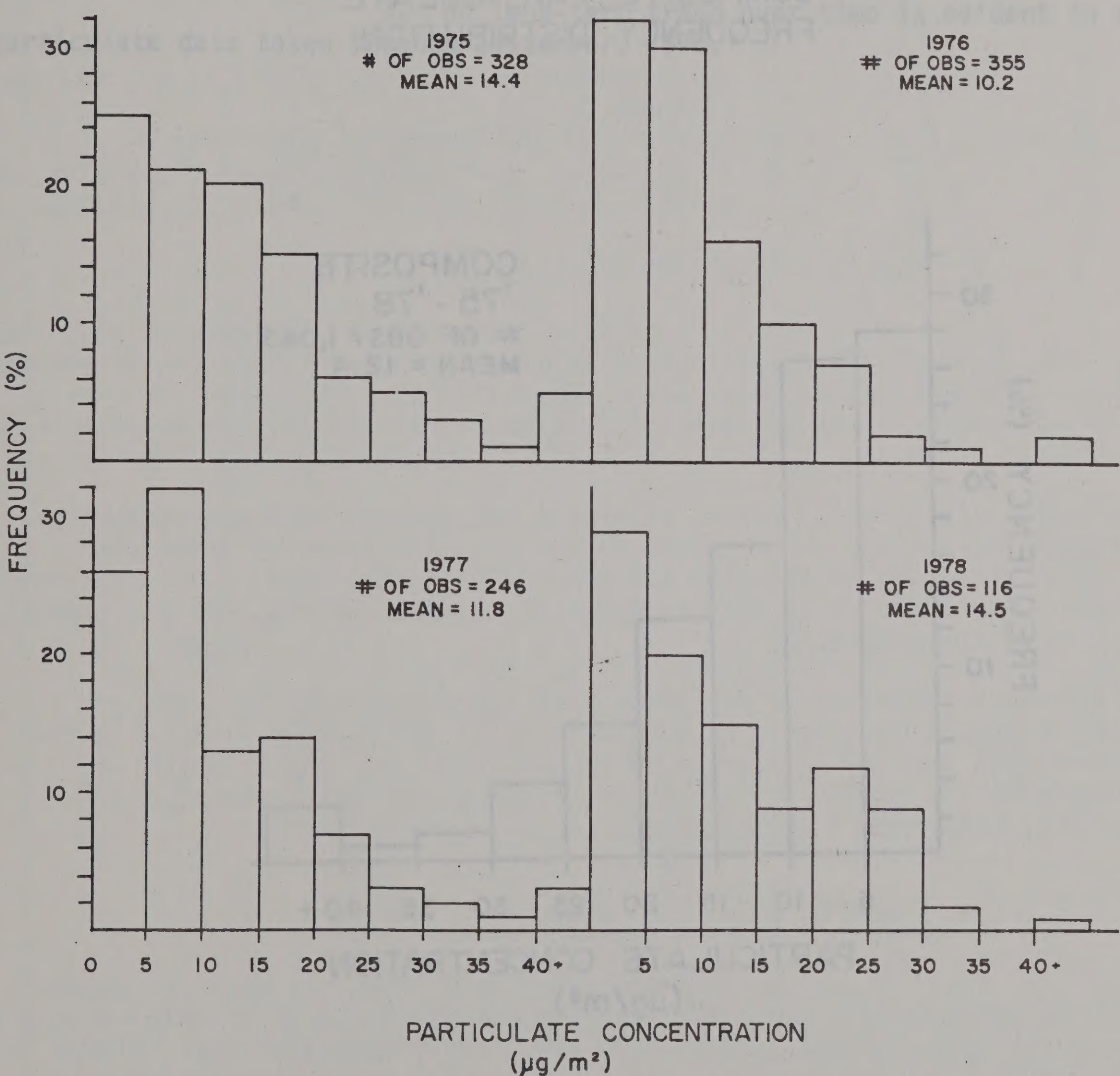
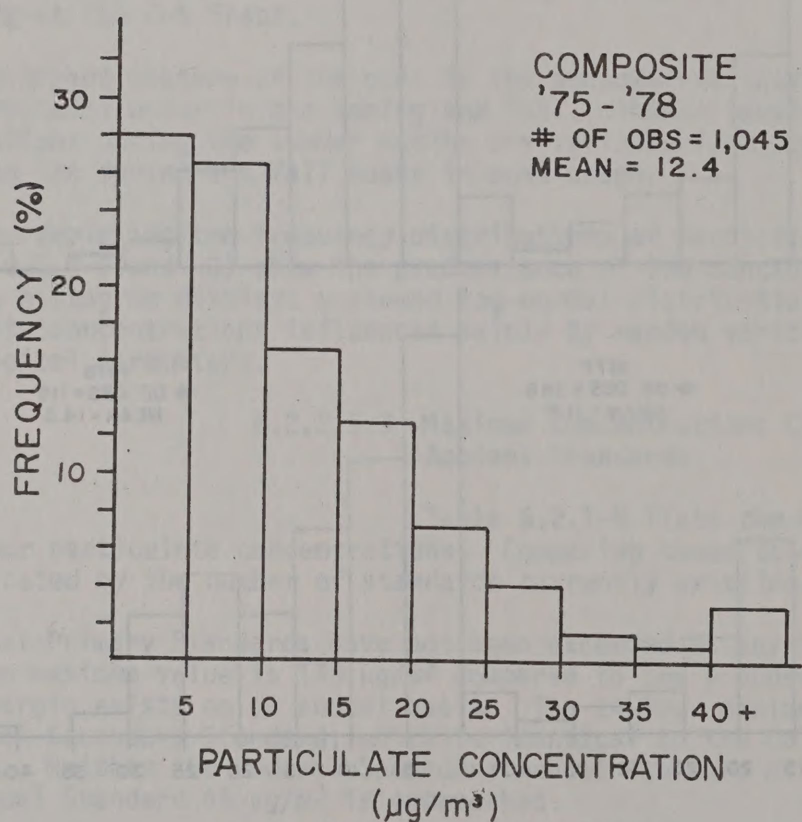


FIGURE 6.2.2-3
COMPOSITE PARTICULATE
FREQUENCY DISTRIBUTION



6.2.2.6 Conclusions

1. Particulates in the area of the C-b Tract are primarily rural in origin, particularly those responsible for maximum concentrations.

2. Although firm correlations have yet to be drawn, seasonal trends in particulate concentrations suggest a general meteorological dependence.

3. No long-term trend over time is evident in the particulate data taken through September, 1978.

6.2.3 Visibility

6.2.3.1 Scope and Rationale

The visibility monitoring program has been co-sponsored by the C-b and Rio Blanco Shale Oil Projects. Measurements were taken every sixth day for a total of ten days in the Spring quarter, 1978, and ten days in the Fall. There are no state or federal requirements for visibility monitoring, however, the program is required under the Federal Oil Shale Lease Environmental Stipulations.

6.2.3.2 Objectives

- to establish baseline visibility levels for the Piceance Basin
- to identify any trends in visibility
- to establish correlations between visibility and meteorological and/or air quality parameters.

6.2.3.3 Experimental Design

Visibility data were obtained by means of photographs taken from an observation site approximately eight miles southwest of Piceance Creek on a ridge between Hunter Creek and Dry Gulch. This site was chosen for its proximity to the C-a and C-b Tracts, as well as for its accessability and range of views.

Photographs were taken at hourly intervals throughout the measurement days in each of four views. (See Figure 6.2.3-1). The use of at least two objects in each view enabled the measurement of visual range under a variety of visibility conditions. The locations of the observation site and objects are shown on the Figure.

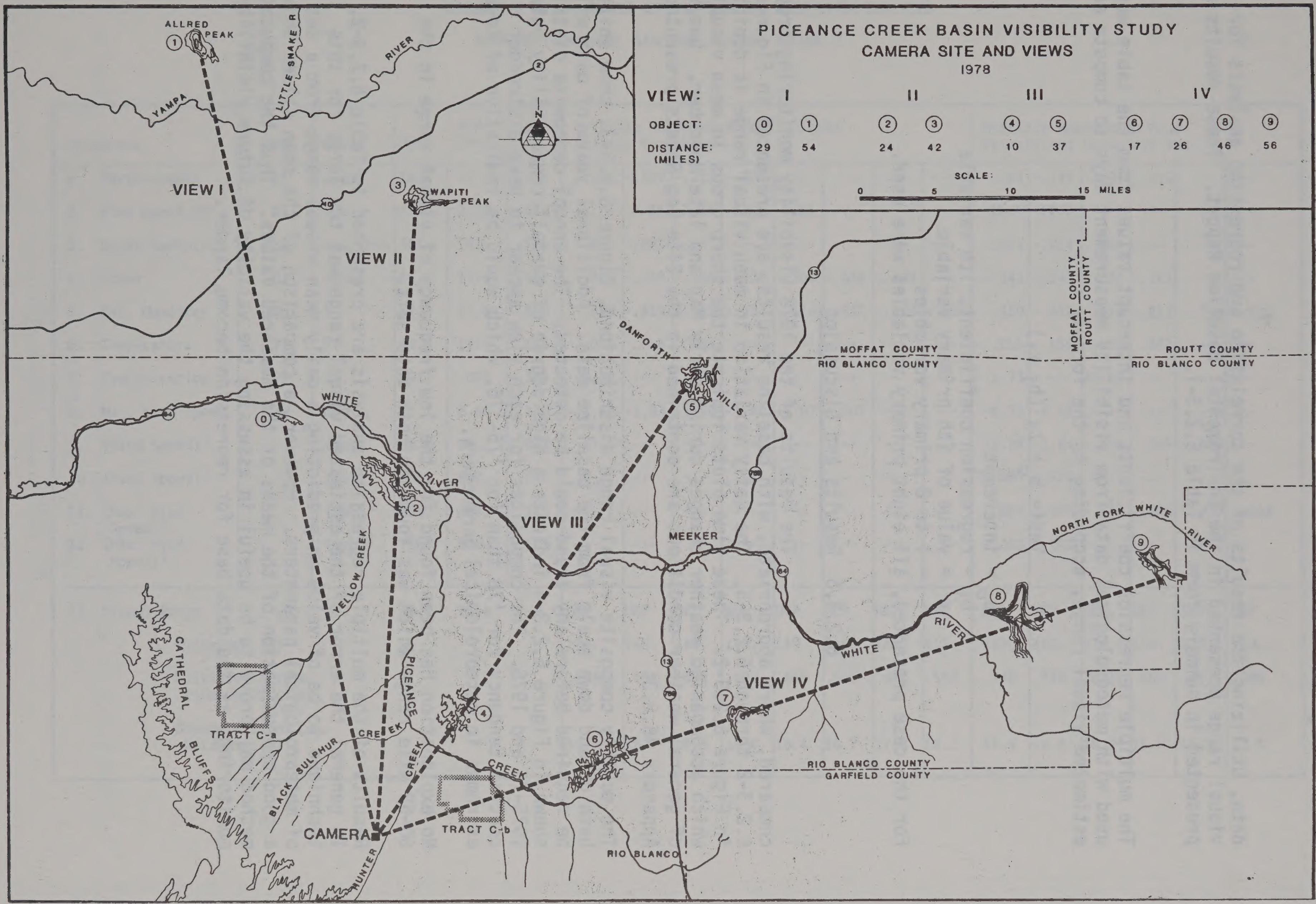
Visual range information is extracted from the photographs by means of optical density measurements on the portions of the photograph representing a given object and the horizon sky directly above it. These densities, together with the actual object-camera distance and the object albedo are used to calculate a visual range.

6.2.3.4 Methods of Analysis

In that there has been only one year of seasonal visibility measurements since the baseline visibility study of 1975-1976, there is no basis for analysis of long term trends in visibility. Visual range results have been compiled and averaged on a per-view and composite basis over monthly, seasonal, and annual periods to facilitate comparison with baseline data.

There has been analysis of a different kind applied to the 1978 visibility

FIG. 6.2.3-1


PICEANCE CREEK BASIN VISIBILITY STUDY
CAMERA SITE AND VIEWS
1978
VIEW: I II III IV
OBJECT: 0 1 2 3 4 5 6 7 8 9
DISTANCE: (MILES) 29 54 24 42 10 37 17 26 46 56
SCALE:
0 5 10 15 MILES
ALLRED PEAK
YAMPA
LITTLE SNAKE R
RIVER
WAPITI PEAK
VIEW I
VIEW II
VIEW III
VIEW IV
DANFORTH HILLS
MOFFAT COUNTY
RIO BLANCO COUNTY
ROUTT COUNTY
WHITE RIVER
MEEKER
NORTH FORK WHITE RIVER
YELLOW CREEK
PICEANCE CREEK
BLACK SULPHUR CREEK
CATHEDRAL BLUFFS
TRACT C-a
TRACT C-b
CAMERA
HUNTER
RIO BLANCO
GARFIELD COUNTY

data, utilizing the results of the correlation and regression analysis for visual range presented in the Enviromental Baseline Report. These results are presented in summary form in Table 6.2.3-1.

The multiple regression coefficients and intercept values from the table were used with meteorological data from visibility measurement days to compute an estimated visual range, according to the formula

$$Yest = b_0 + \Sigma_i (b_i x_i)$$

b_0 = intercept
b_i = regression coefficient, ith variable
x = value of ith primary variable
i = 1 to 8 primary variables

For the case presented, all eight primary variables were used.

6.2.3.5 Results and Discussion

The results of the 1978 visibility monitoring program, compared, where appropriate, with baseline results, are presented in Figures 6.2.3-2 through 6.2.3-5. The daily variation in mean visual range is depicted in Figure 6.2.3-2. These time plots indicate the sharp drops in mean visual which accompanied weather changes during early May and late November. Descriptions of general weather conditions are contained in the Site Log Sheets presented in Appendix A6.2.3.

The monthly composite visual range distributions, Figure 6.2.3-3, show shifts both up and down scale from the baseline data. Additional years of data will be required before any trend could be detected. The annual composite distributions shown in Figure 6.2.3-4 indicate a high degree of overall comparability between 1975-76 and 1978. The composites for each view appear to have a stronger central tendency for '78 than for '75-'76, which would be indicative of fewer extremes in meteorological parameters.

No explanation has been found for the low frequency of visual range in the 60-69 mile range which was found in both data sets.

Results of the multiple regression analysis are presented in Table 6.2.3-2. In general the error of the estimated visual range was too large for this technique to be of value in predicting a daily mean visual range from a set of meteorological parameters. However, a comparison of the mean values shows a good approximation of the means of the measured values. Thus the computation method may prove to be useful in assessing the validity of future visibility monitoring, as the data base for regression become larger.

Table 6.2.3-1

SUMMARY OF VISUAL RANGE CORRELATION AND REGRESSION ANALYSES

FROM ENVIRONMENTAL BASELINE REPORT, VOLUME 3

Parameter	Sym	Units	Mean	Std Dev.	Coef. Corr.	Multiple Regression Coefficients Primary Variables								Multiple Regression Coef. Primary and Secondary Var.					
1. Particulates	PA	μg/m³	11.7	12.5	-.125	-.196	-.209	-.213	-.204	---	---	---	---	-.184	-.189	-.197	-.220	---	---
2. Wind Speed-30'	WS	mph	6.92	3.35	-.072	2.79	2.84	2.84	2.81	2.83	---	---	---	15.1	14.9	---	---	---	---
3. Solar Radiation	SR	langleys	364.	182.	.118	-.002	-.002	---	---	---	---	---	---	-.014	-.014	-.004	---	---	---
4. Ozone	OZ	μg/m³	54.4	17.6	-.111	-.261	-.258	-.266	-.236	-.264	-.340	-.409	---	-.141	-.141	-.233	-.247	---	---
5. Rel. Humidity	RH	%	52.7	17.6	-.560	-.809	-.819	-.815	-.834	-.819	-.837	-.829	-.694	-.819	-.822	-.810	-.812	-.738	-.722
6. Temperature	TP	°F	44.0	17.4	.114	.070	.068	.062	---	---	---	---	---	.155	.155	.063	.047	---	---
7. Precipitation	PP	in.	.021	.078	-.304	-6.42	---	---	---	---	---	---	---	-1.73	---	-6.85	---	---	---
8. Max. Wind Speed	MW	mph	17.7	6.64	-.179	-1.80	-1.83	-1.82	-1.80	-1.97	-.607	---	---	-6.72	-6.61	---	---	---	---
9. (Wind Speed)^2		(mph)^2	58.6	56.7	-.022	---	---	---	---	---	---	---	---	-1.88	-1.84	-.184	.185	.260	---
10. (Wind Speed)^3		(mph)^3	586.	847.	.031	---	---	---	---	---	---	---	---	.080	.079	---	---	---	---
11. (Max. Wind Speed)^2		(mph)^2	356.	257.	-.145	---	---	---	---	---	---	---	---	.080	.079	-.046	-.046	-.070	-.018
12. (Max. Wind Speed)^3		(mph)^3	7960.	8304.	-.103	---	---	---	---	---	---	---	---	-.003	-.002	---	---	---	---
13. Visual Range	VR	mi.	76.1	21.8	---	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP
Intercept (m)						146.	146.	146.	148.	149.	149.	142.	113.	152.	152.	138.	138.	125.	120.
Multiple Correlation Coefficient						.694	.694	.694	.692	.686	.665	.642	.560	.740	.740	.692	.692	.662	.598
Standard Error of Estimate (mi).						16.8	16.7	16.5	16.4	16.4	16.7	17.0	18.2	16.4	16.2	16.9	16.6	16.8	17.8

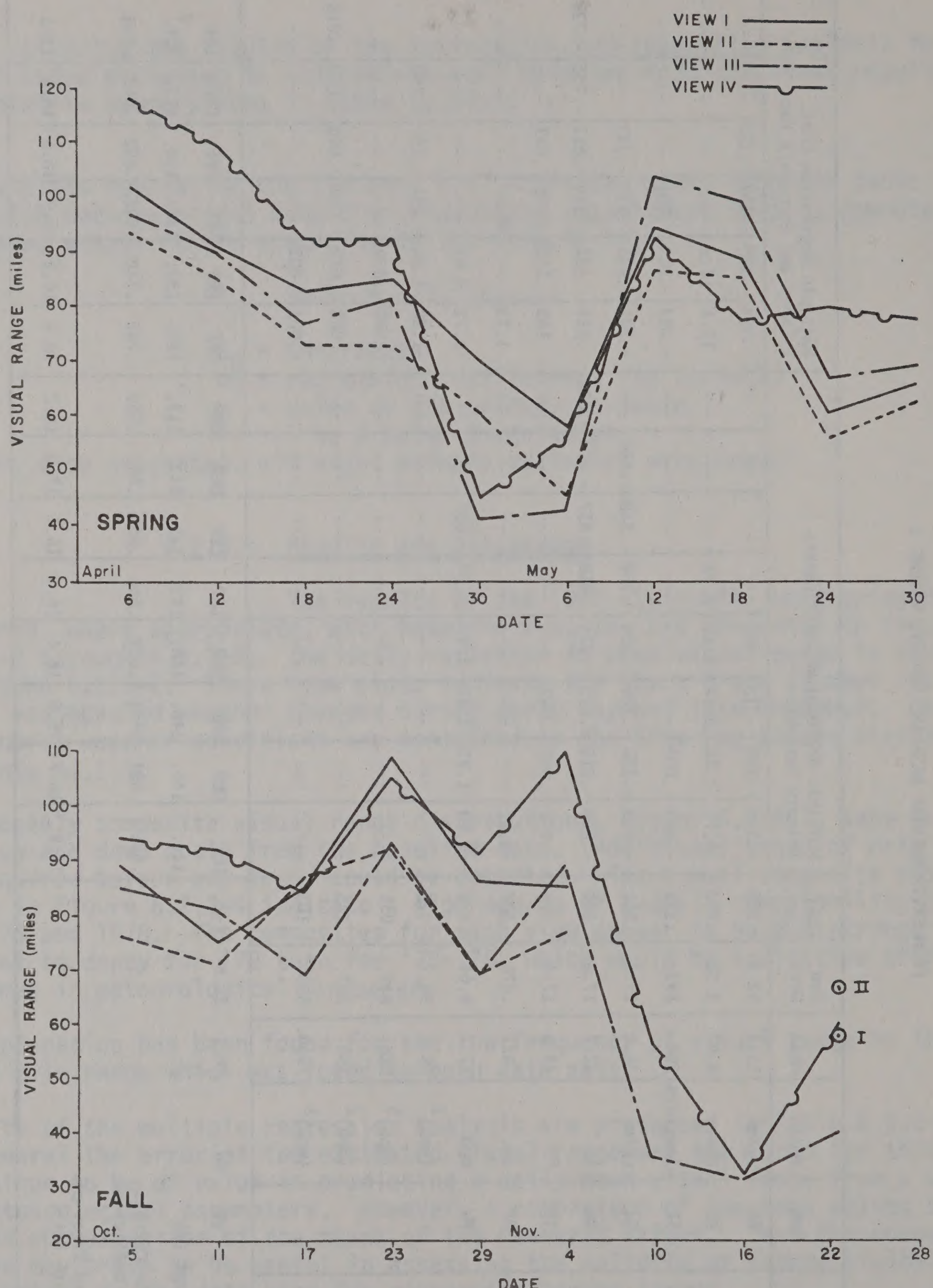


FIGURE 6.2.3-2

VARIATION IN DAILY MEAN VISUAL RANGE FOR EACH VIEW PICEANCE CREEK BASIN, COLORADO SPRING and FALL, 1978

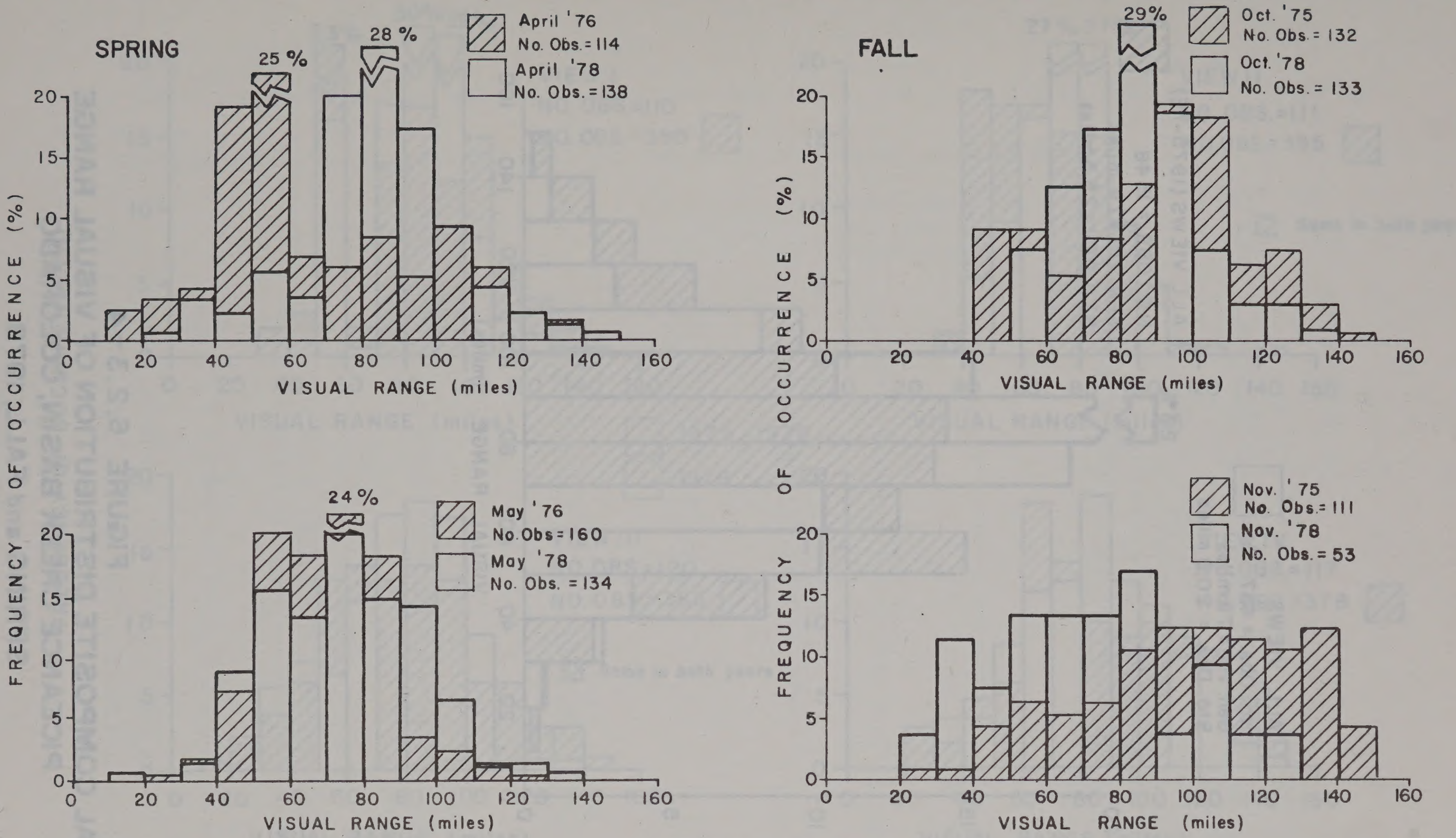


FIGURE 6.2.3-3
MONTHLY COMPOSITE DISTRIBUTION OF VISUAL RANGE
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

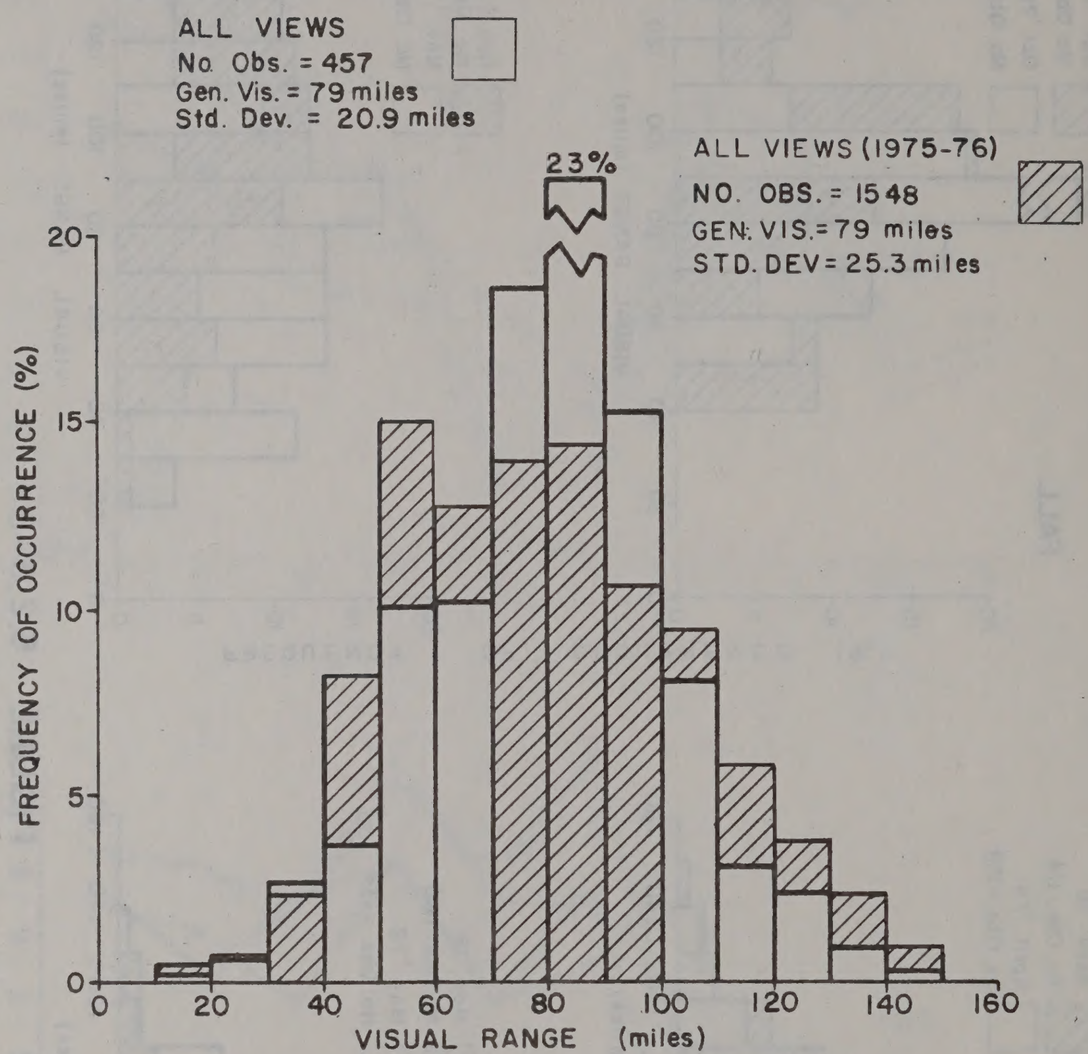


FIGURE 6.2.3-4
ANNUAL COMPOSITE DISTRIBUTION OF VISUAL RANGE
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

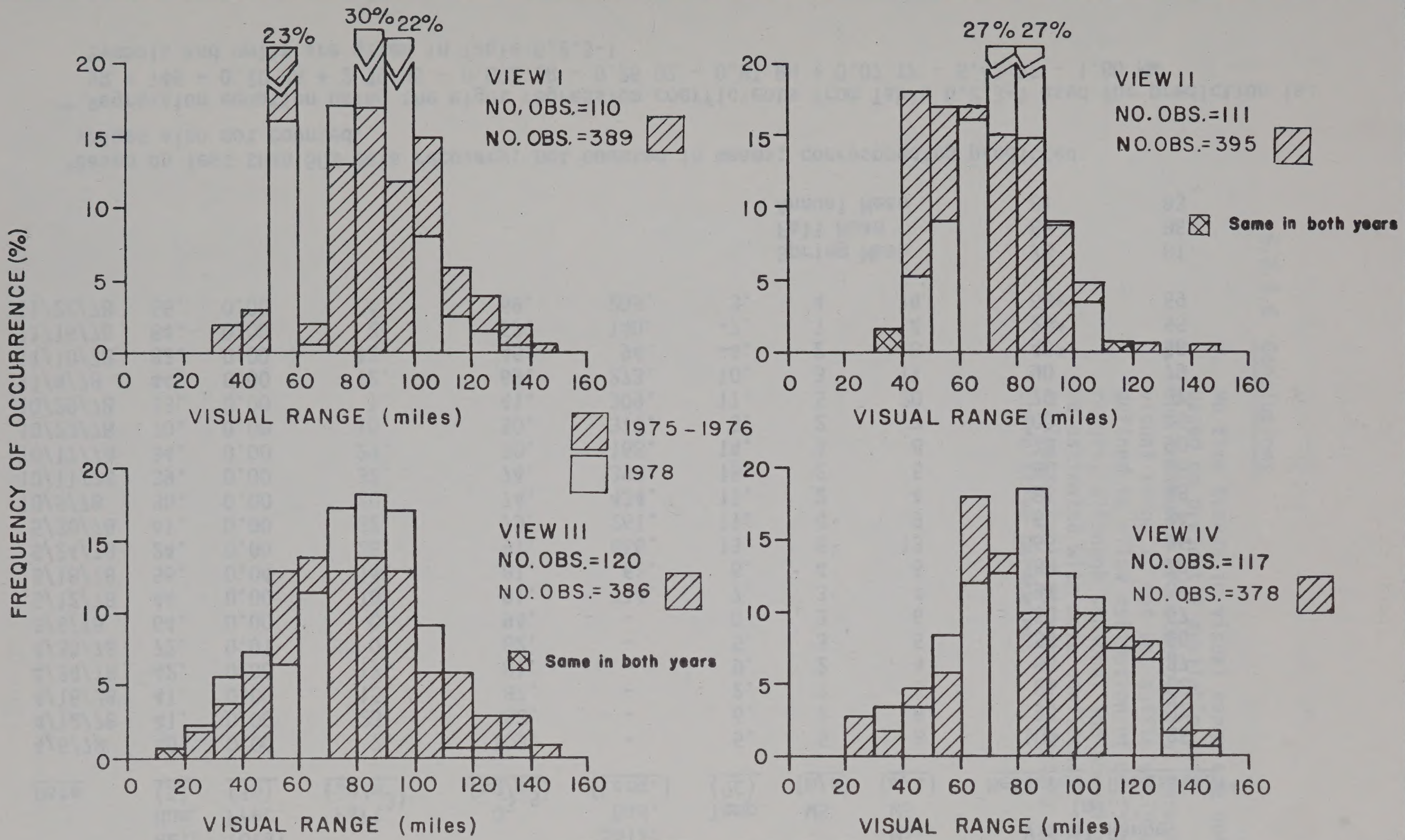


FIGURE 6.2.3-5
ANNUAL DISTRIBUTION OF VISUAL RANGE IN EACH VIEW
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

Table 6.2.3-2 COMPARISON OF PREDICTED AND ACTUAL VISUAL RANGE FOR 1978

Date	Rel. Hum. (%)	Total Prec. (in)	Part. ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	Solar Rad. (Lang.)	Temp. (°C)	WS (m/s)	Max. WS (m/s)	Visual Range (mi.) Measured	Visual Range (mi.) Predicted**
4/6/78	40.	0.00	7.	103.	-	5.	5	8	102	85
4/12/78	41.	0.00	23.	82.	-	6.	2	6	94	82
4/18/78	41.	0.00	15.	87.	-	2.	2	6	81	82
4/24/78	42.	0.00	17.	81.	-	9.	2	4	83	87
4/30/78	72.	0.01	0	82.	-	5.	3	5	54	66
5/6/78	64.	0.00	0	94.	-	0.	3	6	50	67
5/12/78	44	0.00	18.	91.	714.	7.	3	4	94	85
5/18/78	56.	0.04	14.	81.	62.	6.	4	6	88	78
5/24/78	24.	0.00	28.	91.	656.	13.	8	13	66	95
5/30/78	41.	0.00	22.	79.	261.	11.	4	9	69	84
10/5/78	30.	0.00	20.	74.	434.	11.	2	4	86	98
10/11/78	39.	0.00	32.	74.	398.	15.	2	5	80	86
10/17/78	34.	0.00	29.	80.	168.	14.	4	8	78	90
10/23/78	70.	0.00	10.	50.	316.	3.	2	3	100	75
10/29/78	33.	0.00	1.	41.	309.	11.	5	20	79	87
11/4/78	44.	0.00	12.	69.	273.	10.	3	11	90	79
11/10/78	83.	0.00	12.	45.	94.	-4.	2	8	46*	56
11/16/78	84.	0.00	2.	67.	140.	-7.	1	4	29*	55
11/22/78	55.	0.00	4.	69.	209.	3.	4	14	55*	69
						Spring Mean			78	81
						Fall Mean			86	86
						Annual Mean			81	83

*Based on less than 50% data recovery; not counted in means; corresponding predicted values also not counted.

** Regression equation using the eight regression coefficients from Table 6.2.3-1 used for prediction is:
VR = 146 - 0.20 PA + 2.79 WS - 0.002 SR - 0.26 OZ - 0.81 RH + 0.07 TP - 6.42 PR - 1.80 MW
Symbols and units are given in Table 6.2.3-1

6.2.3.6 Conclusions

1. No time trends in visual range are detectable based on presently available data.
2. The influence of meteorological parameters on visual range is not yet sufficiently well defined to allow estimation of daily visual ranges, although seasonal and annual means may be estimated with more confidence. Additional analysis should attempt to identify additional correlative parameters.

6.3 Meteorology

6.3.1 Climatological Records

6.3.1.1 Scope and Rationale

These climatological parameters include temperature, solar radiation, precipitation, evaporation, relative humidity, and barometric pressure.

The justification for climatological records is primarily to serve as a historical data base to assess climatological effects principally on the biotic portion of ecosystem so they may subsequently be sorted out from potential man-induced effects.

6.3.1.2 Objectives

Objectives are to establish this historical data base and to determine any cyclical or long-term trends that might exist as well as averages and extremes, as appropriate.

6.3.1.3 Experimental Design

Parameters measured, instrumentation used, sampling stations (Figure 6.3.1-1) and min. reporting frequency are presented in Table 6.3.1-1.

6.3.1.4 Methods of Analysis

Table 6.3.1-2 presents a summary of data formats and analysis along with station identification. Data presentation and analysis techniques include Box-Jenkins time series for temperature, time series plots for all Class I indicator variables, histograms, plots and tables. In the cases of solar radiation and precipitation the methods include techniques for monthly and annual totals in presence of missing data.

6.3.1.5 Results and Discussion

6.3.1.5.1 Temperature

Annual mean temperatures at the Tract (Sta.AB23) have averaged between 6 and 7°C over the past four years. Box-Jenkins analysis of the monthly means (Table A6.3.1-1) yielded a total (4 year) series mean of 6.05°C with no discernable trend; projections over the next year with 95% confidence using a seasonal autoregressive model are shown on Figure 6.3.1-2.

Between-station comparisons (Sta.AB20 vs. AB23) indicate minimum temperatures 18 to 21°C cooler in Piceance Valley than on Tract, due principally to cold air drainage associated with katabatic winds, with Valley temperatures reaching extremes of -43°C.

FIGURE 6.3.1-1
CLIMATOLOGICAL NETWORK

TABLE 6.3.1-1

CLIMATOLOGICAL PARAMETER EXPERIMENTAL DESIGN

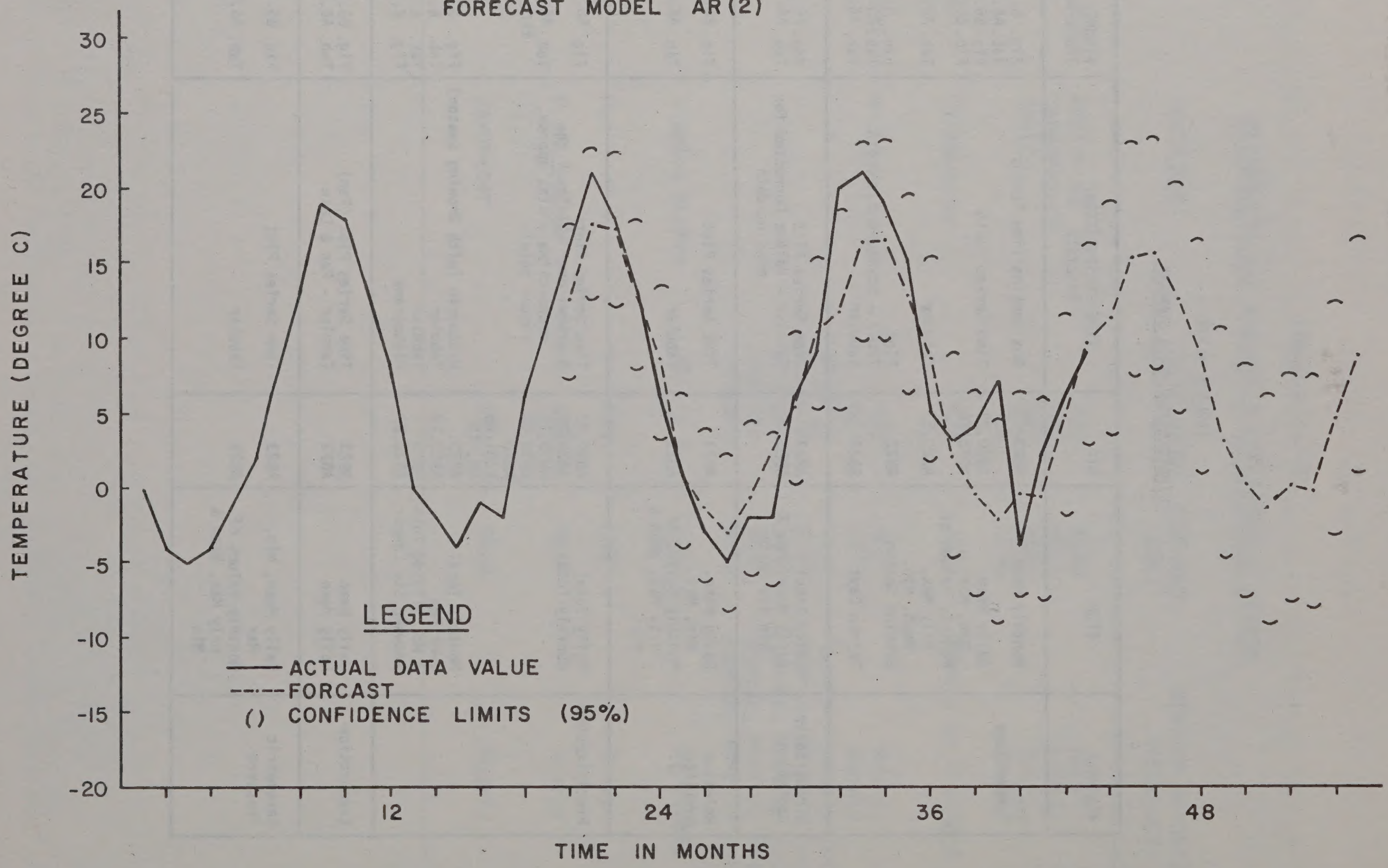
PARAMETER	INSTRUMENT	STATION(S)	COMPUTER CODE	MINIMUM REPORTING FREQUENCY
Air Temperature	Aspirated Temperature Sensor	020	AB20	Hourly
		023	AB23	Hourly
		042	AD42	Hourly
		056	AD56	Hourly
Direct Solar Radiation	Pyranometer	023	AB23	Hourly in daylight
Precipitation	Weighing Bucket	020	AB20	Hourly
		023	AB23	Hourly
		USGS015	WU15	Approx. Monthly Totals
		USGS022	WU22	Approx. Monthly Totals
		USGS050	WU50	Approx. Monthly Totals
		USGS058	WU58	Approx. Monthly Totals
		USGS070	WU70	Approx. Monthly Totals
	Tipping Bucket	MC1 to 9, 13	BC01 to 09, 13	Bi-Weekly
Evaporation	Pan	023	AB23	Daily
Relative Humidity	R. H. Sensor	023	AB23	Hourly
Barometric Pressure	Barometer	023	AB23	Hourly

TABLE 6.3.1-2

CLIMATOLOGICAL DATA SUMMARY

VARIABLE	ITEM	STA.	TYPE PRESENTATION/ ANALYSIS	FIGURE/ TABLE NO.
Air Temperature	Monthly Mean	AB23	Box Jenkins Time Series	Fig. 6.3.1-2 Tab. A6.3.1-1
	Daily Mean, Min, Max	AB20,23 AD42,56	Time Series Plots	Fig. B6.3.1-2,3 Fig. B6.3.1-4,5
	Monthly Values of Hrly Max, Mean, Min,	AB20,23	Tabular	Tab. A6.3.1-2
	Growing Season	AB23	Plot Table - Start, End, Length	Fig. 6.3.1-3 Tab. A6.3.1-3
	Degree Days	AB23	Tabular	Tab. A6.3.1-3
Direct Solar Radiation	Daily Total	AB23	Time Series Plot	Fig. B6.3.1-7
	Daily Mean; Max & Min for Month	AB23	Tabular - Values Corrected for missing data	Tab. A6.3.1-4
Relative Humidity	Daily Mean, Min, Max	AB23	Time Series Plot	Fig. B6.3.1-1
	Monthly Values of Hrly Max, Mean & Min	AB23	Tabular	Tab. A6.3.1-5
Precipitation	Daily Total	AB20,23	Time Series Plots	Fig. B6.3.1-9, 10
	Monthly Total	AB20,23 WU15,22 WU50,58 WU70 BC01 to 09, 13	Averages over all Sta $\pm$ the micro-climate sta; approx. annual total	Tab. A6.3.1-6a thru 6d
	Monthly Total	AB23	Histogram (with Growing Season)	Fig. 6.3.1-3
	1-Hr Max	AB20,23	Tabular	Tab. 6.3.1-3
	3 Mo. Sliding Total	AB23	Tabular	Tab. 6.3.1-3
	Between Sta Compar.	AB20,23	Histograms	Fig. 6.3.1-4
Evaporation	Daily Mean	AB23	Time Series Plot (Pan)	Fig. B6.3.1-11
	Daily Mean	AB23	Tabular - Pan & Lake	Tab. A6.3.1-7
Barometric Pressure	Daily Mean, Min, Max	AB23	Time Series Plot	Fig. B6.3.1-6
	Monthly Values of Hrly Max, Mean & Min	AB23	Tabular	Tab. A6.3.1-8

FIGURE 6.3.1-2
TEMPERATURE AT TRAILER AB23 (10M LEVEL) vs. TIME
FORECAST MODEL AR(2)



Growing season and degree-day data are presented on Table A6.3.1-3. Growing seasons over the past four years have varied from 111 days in 1976 to 144 days in 1977, yet the degree-days referenced to 18°C (Munn (1970)) were highest in 1978 (223°C-days) indicating the highest average temperatures and corresponding to a growing season of 124 days.

6.3.1.5.2 Solar Radiation

Direct solar radiation as measured by the pyranometer varies from a monthly average of 620 langleys per day in June near summer solstice to approximately 130 in December near winter solstice. This variation approximates the yearly cycle in the peaks of cosine of the sun's zenith angle. Values presented in Table A6.3.1-4 have been corrected for missing data by applying a correction factor. This correction factor is the ratio of average daylight hours per month to pyranometer channel "uptime" hours per month for cases where uptime exceeds 50% of the daylight hours per month. Values obtained for the Tract in June have been compared with values obtained for 40°N latitude (approx. Tract latitude) from Sellers, Physical Climatology (Figure 5):

	TRACT	SELLERS
Clear day peak	744	700 ly/day
Monthly average	620	592

Sellers "average" terms included:

Q,	direct beam solar radiation incident on earth surface	
+q,	diffuse solar radiation incident on earth surface	389 ly/day
Cr,	backscattering by clouds	164
Ar,	backscattering by air molecules, dust, water vapor	39
	Total	592 ly/day

Additional terms in Sellers peak (cloudless, dry day)

C_a,	(no) absorption by clouds	25
A_a,	(no) absorption by air molecules, dust, water vapor	83
	Total	700 ly/day

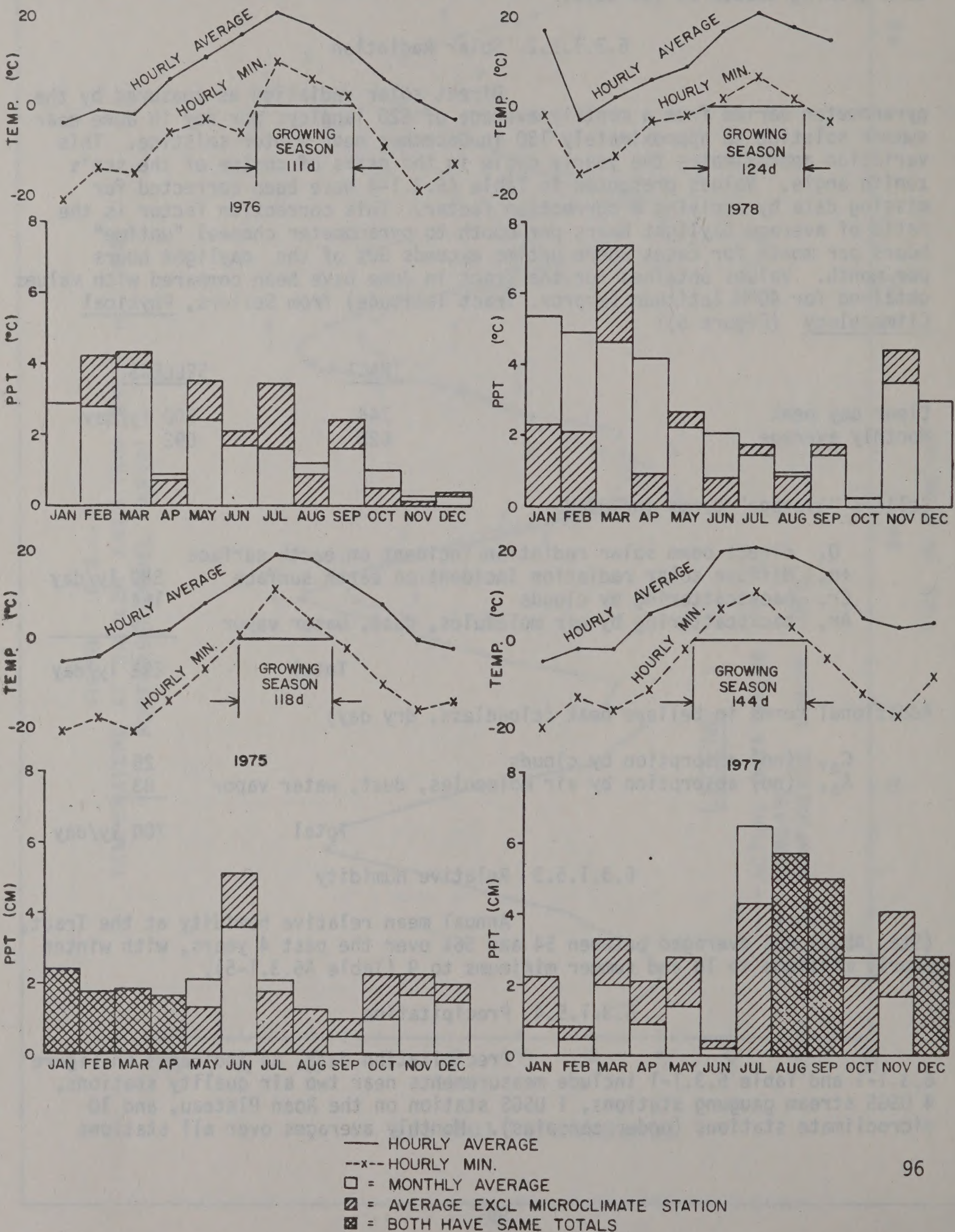
6.3.1.5.3 Relative Humidity

Annual mean relative humidity at the Tract, (Sta. AB23) has averaged between 54 and 56% over the past 4 years, with winter hourly minimums to 10 and summer minimums to 9 (Table A6.3.1-5).

6.3.1.5.4 Precipitation

Precipitation data, as indicated on Figure 6.3.1-1 and Table 6.3.1-1 include measurements near two air quality stations, 4 USGS stream gaugung stations, 1 USGS station on the Roan Plateau, and 10 microclimate stations (under canopies). Monthly averages over all stations

FIGURE 6.3.1-3
MONTHLY TOTAL PRECIPITATION
AND TEMPERATURE VARIATIONS



are presented in Tables A6.3.1-6a through -6d. Monthly averages at the USGS stations are approximate only, inasmuch as sampling of these stations is somewhat randomized. Annual totals (± the microclimate stations and excluding the Roan Plateau station for which precipitation is higher than the Tract locale), 3-month running totals and the 1-hour peaks for the past four years are given on Table 6.3.1-3. Monthly histographs for each year are presented on Figure 6.3.1-3, along with growing season information. Although 1977 was the wettest of the four years, (35.7 cm), its distribution was such that it came too late in the year to be a major influence on productivity (see the late peak in May-July), a fact borne out in the ecosystem interrelationships section. Lightest annual precipitation was 23.6 cm in 1976. Peak down-pours for a 1-hour duration have reached 4.3 cm on September 3, 1977. Between-station comparisons for AB20 and AB23 are portrayed on Figure 6.3.1-4 as histograms, showing the local nature of precipitation between Tract (AB23) and Valley (AB20). Differences in monthly totals of as much as 5.4 cm were observed in September 1977.

6.3.1.5.5 Evaporation

Evaporation during the growing season has been measured by an evaporation pan at Sta. AB23 in 1978. Monthly totals (Table A6.3.1-7) ranged from 17.7 to 27.0 cm, as "pan" values; assuming a 0.7 pan coefficient, lake values respectively range from 12.4 to 18.9 cm.

6.3.1.5.6 Barometric Pressure

Annual mean barometric pressures at Tract Sta. AB23 have averaged approximately 790 mb over the past four years with hourly minimums as low as 753, and hourly maximums as high as 804 mb, (Table A6.3.1-8).

TABLE 6.3.1-3

PRECIPITATION (cm)

YEAR	ANNUAL TOTAL*		3-MONTH TOTAL* (Incl. Micro. Sta)			1-HOUR MAXIMUM	
	EXCLUSIVE OF MICROCLIMATE STATIONS	INCLUDING MICROCLIMATE STATIONS	MAR-APR-MAY	APR-MAY-JUN	MAY-JUN-JUL	AMOUNT	DATE
1975	24.95	24.86	5.74	7.53	8.06	1.19	AUGUST 14
1976	23.64	21.46	8.10	5.91	5.66	0.51	MAY 6
1977	35.74	30.35	4.38	2.52	8.15	4.32	SEPTEMBER 3
1978	34.94	25.51	11.80	8.72	5.93	1.35	MAY 21

* Obtained from Monthly averages over all stations in vicinity of Tract (Excluding the Roan Plateau Station)

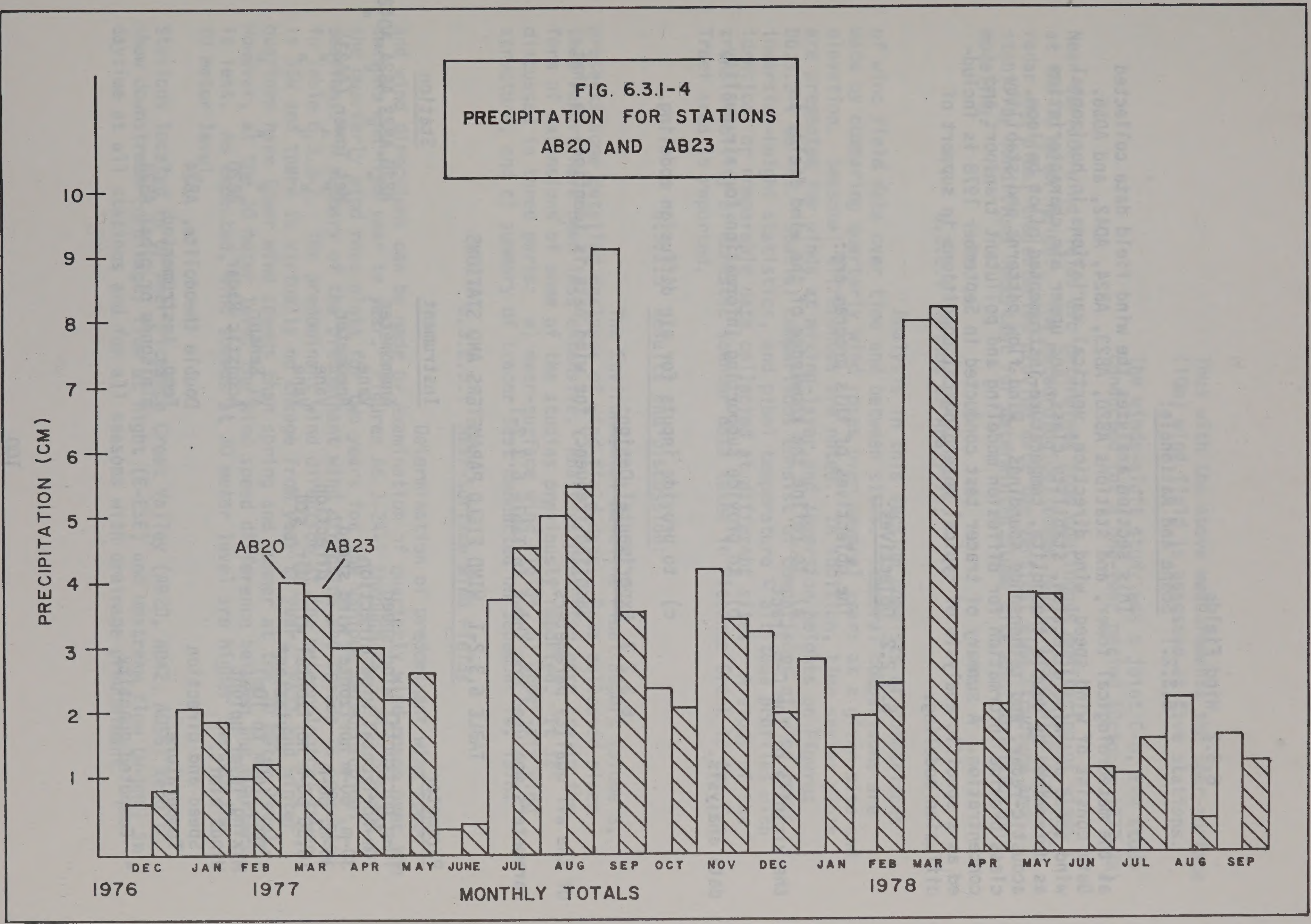


FIG. 6.3.1-4
PRECIPITATION FOR STATIONS
AB20 AND AB23

6.3.2 Wind Fields

6.3.2.1 Scope and Rationale:

This section analyzes the wind field data collected at the meteorological tower, and stations AB20, AB23, AB24, AD42, and AD56. Data consist of wind speed, wind direction, vertical variations in horizontal wind speed and wind direction, stability class, and upper air characteristics as determined by double theodolite, temperature-instrumented pilot balloon, acoustic-radar, and tethersonde soundings. Wind flow patterns and stability class provide information for diffusion modeling and pollutant transport and concentration. A summary of tracer test conducted in September 1978 is included as a specific analysis of typical meterological conditions in support of diffusion modeling.

6.3.2.2 Objectives:

The objectives of this program are:

a) to refine the knowledge of the wind fields in the vicinity of the C-b Tract.

b) to provide supporting information for air quality data analysis.

c) to provide inputs for air diffusion modeling.

6.3.2.3 Experimental Design:

Sampling frequency for wind data is identical to that of the air quality parameters.

Parameters measured are shown in Table 6.3.2-1.

TABLE 6.3.2-1 WIND FIELD PARAMETERS AND STATIONS

Parameter	Instrument	Station
10-m horizontal wind speed	Anemometer	AB20,AB23,AB24,AD42,AD56
10m-horizontal wind direction	Vane	" " " " "
30-m, 60-m horizontal wind speed	Aneometer	Met Tower (AA23)
30-m, 60-m " " direction	Vane	" " "
10,30 60-m horizontal wind dir. std. deviation*	Vane	" " "
ΔTemp. (60m to 10m)	ΔT Sensor	" " "
Mixing layer height	Acoustic Radar	AB20
Winds aloft:		
Speed and direction	Double theodolite,	AB24
Temperature	Temp. instrumented minisonde or pibal	AB24

* Computed quantity

Thus with the above measurements the near-surface (10m) wind field is assessed at five stations.

The winds-aloft study was a joint C-b, EPA study conducted for a one-year period (October 1977-78)

Near-surface wind fields are determined from continuous monitoring of winds at the 10 meter height. The meteorological tower levels along with acoustic radar and pibal trajectories provide data for vertical wind structure and stability conditions important for determining plume rise and for diffusion modeling.

6.3.2.4 Method of Analysis:

Analysis in this section consists of comparisons of wind field data over time and between sites. Temporal comparisons are made by comparing quarterly wind roses over several years at a given site and elevation. Seasonal differences are noted. In addition, time series plots are presented for winds at mixing-layer and inversion heights on Figures B6.3.2-1 to -12. Spatial comparisons consist of comparisons of wind roses, inversion-height statistics, and pibal temperature - altitude profiles with identical or comparable data collected at different sites. A study of the translatability of acoustic sounder data taken in Piceance Creek to the C-b Tract area is reported.

6.3.2.5 Results and Discussion:

The Environmental Baseline Final Report Volume 3, presents some detailed analyses of wind field data. Data collected since that report have been less extensive. Analyses presented here are in the form of extensions of some of the studies previously reported. It is discussed in three parts: a) near-surface wind fields, b) upper-air wind structure, and c) summary of tracer test conducted on Sepember 14, 1978.

6.3.2.5.1 Near-Surface Wind Fields

Determination of predominant wind speed and wind directions can be made by examination of quarterly wind-roses over the seasons and from year to year. Figures A6.3.2A-1 through A6.3.2A-8 present the quarterly wind rose plots for two years for the various meteorological stations. A summary of the predominant wind direction and speeds is presented in Table 6.3.2-2. The predominant wind direction at the meteorological tower is SSW and there is virtually no change from year to year. Fall and winter quarters have lower wind speeds than spring and summer at the 10 meter level. However, at the 30 meter level the wind speed difference between the quarters is less. As expected, wind speeds at 30 meter level are higher than at the 10 meter level.

Stations located in or near Piceance Creek Valley (AB20, AD42, AD56) tend to show downstream (drainage) flow at night (E-ESE) and upstream flow (W-WNW) in daytime at all stations and for all seasons with drainage predominant.

TABLE 6.3.2-2 WIND ROSE COMPARISON AND OBSERVATIONS

Site	Quarter	Predominant Wind Direction and Speed 1974-1975	1975-1976	1976-1977	1977-1978
Tower (AA23) 10 meter	Fall			SSW (1-3)	SSW (<1)
	Winter			SSW (1-3)	SSW (1-3)
	Spring			SSW (5-8)	SSW (3-5)
	Summer			SSW (5-8)	SSW (5-8)
Tower (AA23) 30 meter	Fall	S (5-8m/sec)	SSW (5-8)	SSW (5-8)	SSW (5-8)
	Winter	SSW (5-8)	SSW (5-8)	SSW (8-11)	SSW (3-5)
	Spring	SSW (5-8)	SSW (5-8)	SSW (8-11)	S (3-5)
	Summer	SSW (5-8)	SSW (5-8)	SSW (5-8)	SSW (5-8)
AB20 10 meter	Fall			E (1-3)	
	Winter				
	Spring				ESE (1-3)
	Summer				E (1-3)
AD42 10 meter	Fall				
	Winter				
	Spring				ESE (1-3)
	Summer				E (1-3)
AD56 10 meter	Fall				
	Winter				
	Spring				SE (1-3)
	Summer				SE (1-3)

6.3.2.5.2 Upper-Air Wind Structure

Three analyses are presented in this section: a) Acoustic radar inversion and mixing data and the representativeness of the data to the C-b Tract area; b) double-versus single-theodolite pibal profiles; and c) atmospheric stability.

a) Inversion and Mixing Heights

Temperature inversion heights are measured by means of an AeroVironment Model 300 Acoustic Radar. The instrument was reactivated at Piceance Creek station AB20 in November 1977. The output of the instrument is a continuous strip chart record of reflected sound signals associated with thermal turbulence signatures; such signatures vary in character depending on whether the atmosphere is stable or unstable. The chart provides a means for determining the height in meters of temperature inversions and mixing layers above ground level.

Figure A6.3.2A-9 shows average monthly inversion heights for months of December 1977 through August 1978. The months are grouped by quarters to show seasonal patterns. Plots have been limited to hours with expectation of occurrence greater than 0.5. Winter months show average inversion heights of about 175 meters above ground level. The average afternoon onset time is 1830 hours and breakup the next morning about 1100 for an average duration of 16-1/2 hours. Spring months show average inversion heights of 200 meters. Onset time is about 1 hour later at 1930 and breakup is about 0900 the next morning. Average duration is 13-1/2 hours. The plots show the greatest average height range for the summer months with June averaging 300 meters, July averaging 350 meters, and August with 400 meter average. Duration in summer is shorter with average onset time of 1930 and breakup next morning about 0830 for about 13 hours average duration.

Constant potential temperature and constant pressure lines on a cross section plot of elevation profiles from Piceance Creek to the C-b Tract are presented on Figures A6.3.2A-10 and -11 for two dates corresponding to tethersonde balloon flights. It is expected that inversion height profiles approximate lines of constant potential temperature as they exist on the same date. The acoustic radar is located at station AB20, the lowest point on the profile. Inversion heights in meters above this station can be translated to heights above the meteorological tower and compared with the constant potential temperature lines. The top of the 60 meter meteorological tower translates to 225 ± 25 meters above the acoustic radar at site AB20.

To investigate the translatability of acoustic radar data observed in Piceance Creek to the C-b Tract, a comparison of inversion height measurements taken in 1975 and 1976 were made. Two acoustic radars were operational, one at the meteorological tower site and the other in Piceance Creek first at site AC21 and in June 1976 moved to site AC20. It has been possible to screen from the statistics inversions that were observed concurrently at both stations. Table 6.3.2-3 shows the monthly mean inversion duration and heights of the concurrent

TABLE 6.3.2-3 MONTHLY MEAN INVERSION HEIGHTS OBSERVED CONCURRENTLY AT TWO SITES

Site	Year	Month	Mean(Hours) Duration	Mean Max. Height(m)	Mean Min. Height(m)	Mean Avg. Height(m)
AB21	75	Nov.	18.09	278.11	65.36	198.29
AB23	75	Nov.	12.73	161.85	45.47	99.09
AB21	75	Dec.	15.50	260.91	65.84	167.34
AB23	75	Dec.	16.80	195.99	60.05	113.57
AB21	76	Jan.	11.38	399.48	143.18	292.76
AB23	76	Jan.	14.31	219.99	65.04	145.43
AB21	76	Feb.	17.38	369.38	98.03	268.15
AB23	76	Feb.	15.06	322.59	52.65	161.89
AB21	76	Mar.	12.82	322.62	57.14	218.24
AB23	76	Mar.	10.85	191.18	60.13	123.97
AB21	76	Apr.	14.38	307.39	44.81	212.67
AB23	76	Apr.	10.38	150.04	49.99	98.76
AB21	76	May	8.40	459.09	208.42	370.88
AB23	76	May	10.20	250.03	70.01	157.52
AB21	76	Jun.	7.00	569.98	249.94	480.52
AB20	76	Jun.	8.56	508.25	203.68	394.03
AB23	76	Jun.	9.00	262.04	81.96	159.68
AB20	76	Oct.	12.83	392.58	138.56	313.74
AB23	76	Oct.	11.67	250.04	88.32	164.26

observations at each site. Figure A6.3.2A-10 and A5.3.2A-11 also show June and October 1976 monthly max, mean, and min inversion heights plotted on the elevation profiles of constant potential temperature surfaces for specific dates. The constant potential temperature surfaces were determined by tethersonde flights on the dates.

Mixing heights are also obtained from the acoustic radar records. As the ground-based inversion begins to breakup in the morning, surface temperature may rise faster than the upper air temperature resulting in a condition described as an inversion aloft. The temperature-altitude profile is similar to that in Figure 6.3.2-1 with the mixing height increasing until it is equal to inversion height. Similar conditions can occur with movements of warm and cold fronts. The air within the mixing height layer is described as neutral or unstable and provides for good mixing and diffusion of stack emissions.

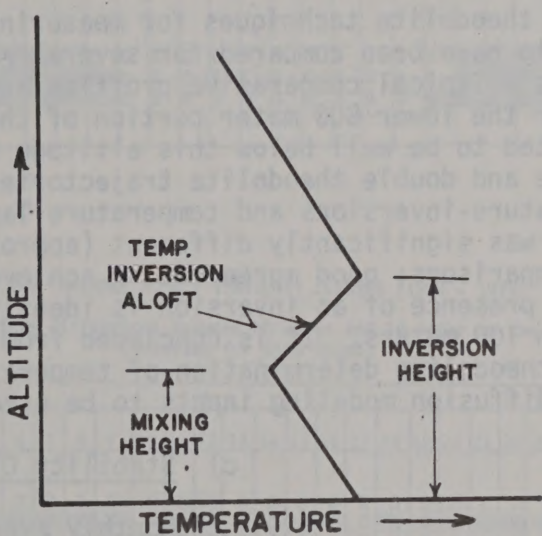


Figure 6.3.2-1 Temperature-Altitude Profile of an Elevated Inversion

However, the air layer between the mixing height and the top of the temperature inversion (increasing temperature with altitude) is stable and very little diffusion of stack emissions occurs in this air layer. Stack emissions below the mixing height are constrained by the inversion "lid". Stack emissions above the inversion height will continue to rise and will not penetrate down through the inversion.

Mixing layer heights have been plotted as a time-series plot in Figure B6.3.2-12. Data are for the period of mid-November 1977 through September 1978. Mixing heights are reported for about 70% of the days with the great majority (about 90%) being at the minimum reporting height of 30 meters. Occasional short duration heights (2 hours) of 100 to 150 meters are reported with a maximum of 425 meters reported in September 1978.

b) Pibal Single-Versus-Double Theodolite Comparison

During the period from November 1977 through October 1978, pilot balloons (pibal) were released twice daily every other day near trailer site AB24 in the early morning and afternoons. Upper air temperature, wind speed, and direction as a function of altitude were determined by tracking the ascent over several minutes and a rise through several thousand meters altitude by double theodolite. Upper-air temperature as a function of altitude was obtained through a temperature-sonde attached to the pibal. The signal transmitted from the temperature-sonde was monitored by radio receivers and used with the trajectory calculations to produce temperature-altitude profiles.

An alternative temperature-altitude profile is obtained from a single theodolite by assuming constant rate of rise and using the temperature-time measurements.

Single and double theodolite techniques for measuring upper air temperatures from the pibal data have been compared for several representative morning and afternoon launches. Typical comparative profiles are shown in Figures A6.3.2A-12 and A6.3.2A-13 for the lower 800 meter portion of the trajectories. Stack plume rise can be expected to be well below this altitude under any meteorological condition. Single and double theodolite trajectories show similar profiles with respect to temperature-inversions and temperature lapse rates. Altitude for a given temperature was significantly different (approximately 100 meters) in 40 percent of the comparisons; good agreement is achieved in 60 percent of the comparisons. The presence of an inversion is identified and its altitude error is no greater than 100 meters. It is concluded from this comparison that either single or double theodolite determination of temperature-altitude profiles is adequate for air diffusion modeling inputs to be used for permit applications.

c) Stability Class Study

Monthly average stability classes have been derived from hourly stability class data. The hourly stability classes were based on delta temperature measurements between the 60 meter and 10 meter levels on the meteorological tower. Pasquill-Gifford stability classes were determined from the slope of the temperature altitude curve (dt/dz) and adjusted for wind speed by the method described in the Baseline Report, Volume 3. Monthly averages by hour from the period from November 1976 through September 1978 are shown in Table 6.3.2-4 for the months containing more than 50% of the data. Unstable, neutral, and stable class are indicated by shading.

Comparison of these data with the baseline period (data shown in Table 6.3.2-5) shows similar patterns for the broad classifications of unstable, neutral, and stable classes. The period for November 1976 through May 1977 is very similar to the same months in the baseline years. However, 1978 data for January-March and July-September tended to reflect a shift in stability class toward the stable end of the scale (toward class F) by one Pasquill-Gifford stability class for most of the monthly averages by hour. No clear explanation can be identified for this.

TABLE 6.3.2-4 AVERAGE HOURLY STABILITY CLASSES (1976 - 1978)

SOURCE: Temperature differences between 60 meter and 10 meter on the Met Tower (Adjusted for Wind Speed)

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
	HOUR																								
Nov. 1976	E	D	D	E	D	E	E	E	D	A	A	B	B	B	B	B	B	D	D	D	E	E	E	E	D*
Dec.	E	E	E	E	E	E	E	E	E	C	B	B	B	B	B	B	B	D	D	D	E	E	E	E	D
Jan. 1977	D	D	E	D	E	D	D	E	D	C	B	B	B	B	B	B	B	C	D	D	D	D	D	D	C
Feb.	E	E	E	E	E	E	E	E	D	C	A	B	B	B	B	B	B	B	C	D	D	D	D	E	D
Mar.	D	D	D	D	D	D	D	C	B	B	C	C	C	C	C	C	C	B	C	D	D	D	D	D	C
Apr.	D	E	E	E	D	E	D	B	B	B	B	B	C	C	C	C	C	B	C	D	D	E	D	D	C
May *	D	D	D	D	D	D	D	B	C	C	D	C	C	D	D	D	D	D	C	D	D	D	D	D	C
June[1]																									
July[1]																									
Aug.[1]																									
Sept.[1]																									
Oct.[1]																									
Nov.[1]																									
Dec.[1]																									
Jan. 1978	E	E	E	E	D	E	E	E	E	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
Feb. *	E	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
Mar. *	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
Apr.[1]																									
May[1]																									
June[1]																									
July *	F	F	F	F	F	F	F	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	F	E
Aug. *	F	F	F	F	E	E	E	E	D	D	C	C	C	C	C	D	D	D	D	E	E	E	F	F	E
Sept. *	F	F	F	F	F	F	F	E	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E

TABLE 6.3.2-5 AVERAGE HOURLY STABILITY CLASSES (1974 - 1976)

SOURCE: Temperature differences between 60 meter and 10 meter on the Met Tower (Adjusted for Wind Speed)

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
	Hour																								
Nov.*																									
Dec.*																									
Jan. 75	D	D	D	D	D	D	D	D	E	E	E	E	D	D	D	D	D	D	D	E	D	D	D	D	D
Feb.	E	E	E	E	E	E	E	E	E	D	D	C	D	C	C	D	D	E	E	E	E	E	E	E	E
Mar.	D	D	D	D	D	D	D	D	C	C	C	C	C	C	D	D	C	C	D	D	D	D	D	D	D
Apr.	D	D	D	D	D	D	D	B	C	C	C	C	C	C	C	C	C	C	C	D	D	D	D	D	C
May	D	D	D	D	D	D	D	B	B	B	C	C	C	C	C	C	C	C	C	C	D	D	D	D	C
June	E	E	E	E	E	E	D	B	D	B	B	C	C	B	C	C	C	C	C	C	D	D	E	E	D
July	-	-	-	MISSING DATA					-	-	-	B	B	B	B	B	B	C	-	-	-	-	-	-	B
Aug.	F	F	F	F	F	E	F	E	C	B	C	C	C	C	C	C	C	C	D	E	E	F	E	E	D
Sept.	F	E	E	F	F	F	F	E	B	B	B	B	B	C	B	B	C	B	E	E	E	F	F	F	D
Oct.	E	E	E	E	E	E	E	E	C	B	B	C	B	C	C	C	B	C	D	D	E	E	E	E	D
Nov.	D	D	D	D	D	D	D	D	C	B	B	B	C	B	B	B	B	C	D	D	D	D	D	D	D
Dec.	D	D	D	D	D	D	D	D	C	C	B	B	B	B	B	B	B	C	C	C	D	D	D	D	C
Jan. 76	D	D	D	D	D	D	D	D	D	C	B	B	B	B	B	B	B	B	C	C	D	D	D	D	D
Feb.	D	D	D	D	D	D	D	D	C	C	C	C	C	C	C	C	B	B	C	D	D	D	D	D	C
Mar.	D	D	D	D	D	D	D	C	C	C	B	D	C	C	C	B	C	C	B	C	C	C	C	C	C
Apr.	D	D	D	D	D	D	D	B	B	C	C	C	C	C	C	C	C	C	C	D	D	D	D	D	C
May	E	E	E	E	E	E	D	B	B	B	B	B	B	B	B	B	B	B	C	D	D	E	E	E	C
June	E	E	E	E	E	E	E	C	C	C	C	C	C	C	C	C	C	C	C	D	E	E	E	E	D
July	E	E	E	E	E	F	E	B	B	B	B	B	B	C	B	B	B	B	B	D	E	E	E	E	D
Aug.	E	E	E	E	E	E	E	C	B	B	C	C	C	C	C	C	C	C	C	E	E	E	E	E	C
Sept.	E	E	E	E	E	E	E	D	B	B	B	B	B	B	B	B	B	B	D	D	D	E	E	E	D
Oct.	E	E	E	E	E	E	E	B	B	B	B	B	B	B	B	B	B	C	D	E	E	E	E	E	D

* Partial data only, less than 100% but more than 50%

1 Missing data

Key:

Unstable Class

D Neutral

Stable Class

Table 6.3.2-6 presents the percentage of hours in each stability class for each month. The baseline data are included for comparison. This table also reflects the shift to the more stable classes for 1978.

Typically the hours between 0900 and 1900 are unstable. Nighttime and early mornings for summer and fall are typically stable while winter and spring are neutral stability.

6.3.2.5.3 Summary of Tracer Test Conducted on September 14, 1978

An experiment was conducted on the C-b Shale Oil Tract on September 14 and 15, 1978 with the objective of simulating the transport and dispersion of emissions from an elevated source in the vicinity of the proposed ancillary facility under meteorological conditions conducive to high ground level pollutant concentrations. Oil Shale Tract C-b Development Monitoring Report #1 (1978) contains a complete report of the tests. The results of the meteorological measurements and related analyses for the September 14 test are summarized in Appendix A6.3.2B as relevant analyses of the wind field conditions and gas concentrations under conditions frequently existing on the Tract.

Figure 6.3.2-2 shows isopleths of SF_6 for September 14 constructed from observed data.

In the first hour, high concentrations of SF_6 were detected at the mouth of Cottonwood Gulch. SF_6 was also detected along the Piceance Creek east of the mouth of Cottonwood Gulch. This is definitely due to the influence of the drainage wind system. Concentrations were higher on the southern bank of Piceance Creek than on the northern bank. Air flowing down the northern slope of the creek (drainage) kept the SF_6 from building up on the northern bank.

A similar pattern was observed in the second hour (0700-0800 MDT). In the following hour the tongue flowing down Cottonwood Gulch into Piceance Creek was almost non-existent.

After 0900 MDT, the SF_6 isopleths showed that high concentrations were observed only south of the point of release. Although fumigation of the plume definitely occurred during the hour beginning 0900 MDT, its duration must have been very short and thus did not result in any high concentrations when averaged over an hour. SF_6 was still detected along the creek during the last two hours, not because the plume was over the creek, but because the flow reversal (from drainage to upslope) brought back SF_6 that was earlier transported down the creek.

A number of observations can be deduced from the results of the experiment.

(1) On 14 September, when the synoptic pressure gradients were weak, local meteorology was responsible for the transport and diffusion of pollutants during nighttime and early morning hours. Under such a situation, the synoptic wind flow was not able to establish itself until after mid-day.

Table 6.3.2-6

METEOROLOGICAL SUMMARY: STABILITY CLASS FREQUENCIES (%)

Source: Met. Tower[1] (30' to 200')

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1974 Nov.[2]	Dec.[2]	1975 Jan.	Feb.	Mar.	Apr.	May	June	July[3]	Aug.	Sept.	Oct.	Annual Mean
A	<-1.9			8.3	1.0	1.1	12.0	7.4	8.6	0.0	2.4	5.8	8.1	6.1[4]
B	-1.9 to -1.7			5.5	4.4	10.3	23.5	30.6	25.6	85.7	19.3	23.4	20.6	18.1
C	-1.7 to -1.5			4.1	2.4	16.3	6.9	9.3	6.9	14.3	6.1	5.0	5.7	7.0
D	-1.5 to -0.5			33.0	43.4	60.9	36.3	30.0	27.0	0.0	25.8	13.4	28.3	33.1
E	-0.5 to +1.5			33.3	36.8	11.4	18.1	12.1	18.0	0.0	17.3	24.4	18.6	21.1
F	>1.5			15.8	12.0	0.0	3.2	10.6	13.9	0.0	29.1	28.0	18.7	14.6
Total Percentage				100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

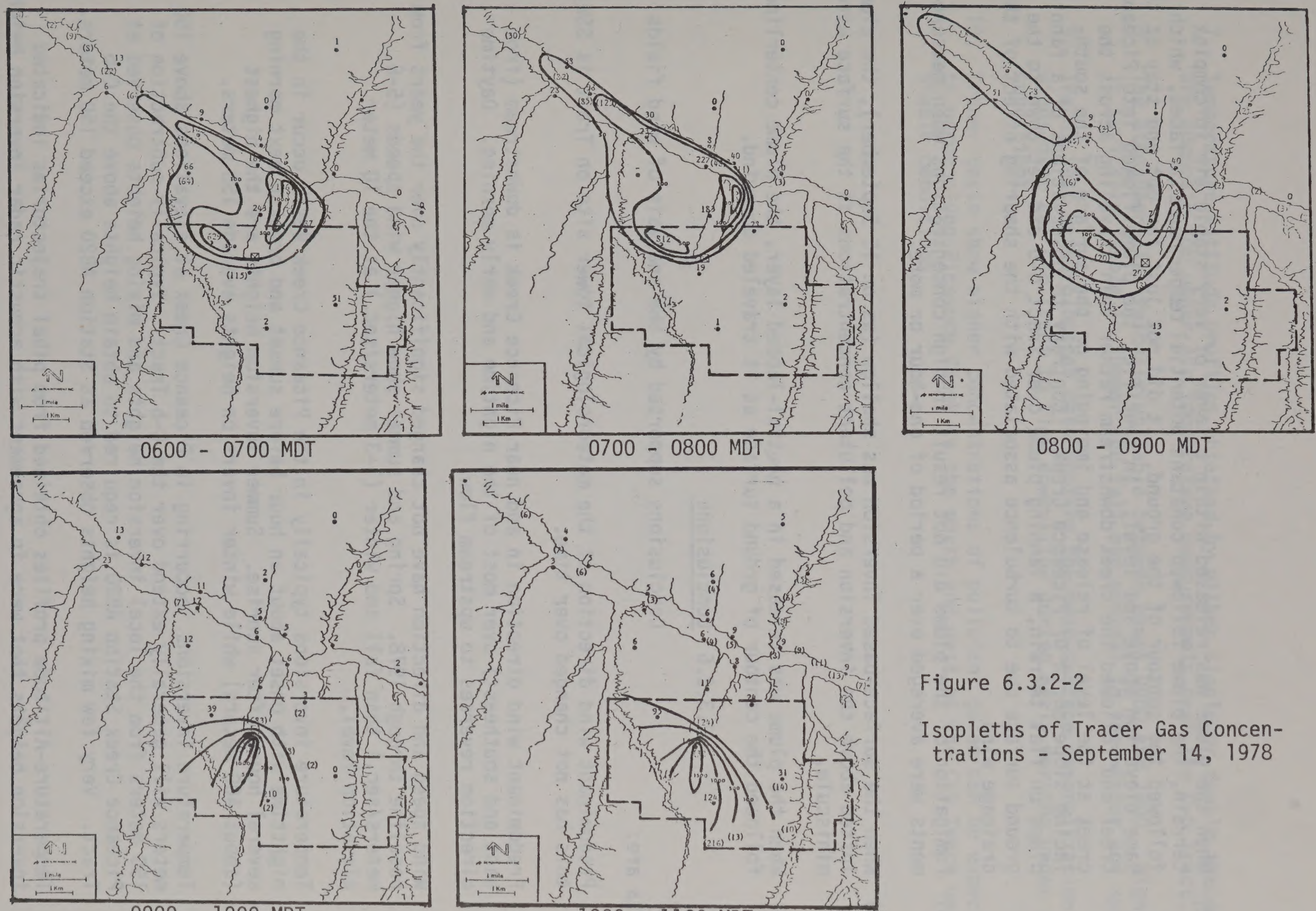
Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1975 Nov.	Dec.	1976 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Annual Mean
A	<-1.9	15.6	18.8	24.9	13.8	19.4	9.5	17.5	4.6	10.3	7.4	13.1	13.6	14.0
B	-1.9 to -1.7	19.7	20.7	21.3	22.1	27.0	21.7	26.3	17.4	30.5	18.4	25.5	20.6	22.6
C	-1.7 to -1.5	6.9	7.4	5.6	7.7	7.9	9.7	6.0	10.0	5.6	6.7	6.1	5.6	7.1
D	-1.5 to -0.5	23.7	21.5	16.6	35.7	28.7	35.2	21.0	32.7	14.1	27.6	17.5	17.9	24.4
E	-0.5 to +1.5	22.9	23.5	21.0	13.8	15.6	17.0	15.6	17.6	19.5	23.0	20.7	21.2	19.3
F	>1.5	11.2	8.1	10.6	6.9	1.4	6.9	13.6	17.6	20.0	16.9	17.1	21.1	12.6
Total Percentage		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1976 Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apr.	May	June[5]	July[5]	Aug.[5]	Sept.[5]	Oct.[5]	Annual Mean
A	<-1.9	18.6	12.3	18.0	12.9	12.9	12.6	5.9						13.3
B	-1.9 to -1.7	19.8	20.7	18.5	27.7	21.6	29.6	13.3						21.6
C	-1.7 to -1.5	4.3	7.1	6.8	7.3	7.9	8.1	9.2						7.2
D	-1.5 to -0.5	12.5	16.2	20.9	12.1	30.1	19.0	46.6						22.5
E	-0.5 to +1.5	27.4	23.7	25.4	26.3	19.3	18.1	17.8						22.6
F	>1.5	17.4	20.0	10.4	13.7	8.2	12.6	7.2						12.8
Total Percentage		100.0	100.0	100.0	100.0	100.0	100.0	100.0						100.0

Table 6.3.2-6 (Continued)

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1977 Nov.[5]	Dec.[5]	1978 Jan.	Feb.[3]	Mar.[3]	Apr.[5]	May[5]	June[5]	July[3]	Aug.[3]	Sept.[3]	Oct.	Annual Mean
A	<-1.9			0.7	0.3	0.3				0.0	0.2	0.0		
B	-1.9 to -1.7			0.3	2.1	0.5				2.3	6.1	2.6		
C	-1.7 to -1.5			4.4	2.9	1.9				5.9	5.7	2.6		
D	-1.5 to -0.5			52.0	48.0	47.4				43.2	35.6	40.1		
E	-0.5 to +1.5			28.2	32.9	24.8				19.5	22.5	23.5		
F	>1.5			14.4	13.8	25.1				29.1	29.9	31.2		
Total Percentage				100.0	100.0	100.0				100.0	100.0	100.0		

1 Adjusted for wind speed
2 Data are suspect and, therefore, not included
3 Partial data
4 Averaged from January-October, excluding July
5 Missing data
6 Data for July and August not available for this report



0600 - 0700 MDT

0700 - 0800 MDT

0800 - 0900 MDT

0900 - 1000 MDT

1000 - 1100 MDT

Figure 6.3.2-2

Isopleths of Tracer Gas Concentrations - September 14, 1978

(2) When the plume was released within a layer of very stable air in complex terrain, the plume followed constant potential temperature surfaces, which followed the contour of the ground. It did not just fan out and stay at the same elevation above sea level. In specific, the plume flowed into Piceance Creek and followed the creek downstream rather than traveling across the creek at the level of release and impinging on the surface of the south-facing slope north of Piceance Creek. Contrary to observations of a fanning plume on flat terrain, a fanning plume over tract C-b did get down to the ground surface due to turbulence associated with the shearing effect of the drainage wind.

(3) Fumigation of the plume did not result in high concentrations when measurements were averaged over a period of one-hour or more.

(4) When the surface-based inversion was shallow (as on 15 September), the plume lofted above the inversion and pollutant concentrations at the surface were miniscule.

(5) When the plume was released in a neutral-lapsed layer, the plume centerline followed the contour of ground surface as it traveled downwind.

6.3.2.6 Conclusions

Conclusions supported by the analysis of wind fields data are:

1. Predominant wind direction at the meteorological tower site on Tract is SSW; this has not changed over time.

2. Predominant wind direction in and near Piceance Creek is downstream (from east and southeast) over most of the nightime and early morning. Daytime direction reverses to upstream flow.

3. Wind speed and direction have not changed significantly over the years from baseline through 1978. Spring and summer show higher wind speeds (5-8 meters/sec.) than fall and winter (1-3 meters/sec.) at the 10 meter elevation level.

4. Temperature inversions typically in the Piceance Creek Basin occur in the nighttime with onset about an hour before sunset and breakup next morning several hours after sunrise. Summer inversion heights are the highest (about 400 meters) while winter inversion heights average 150 meters.

5. Temperature inversions occurring in Piceance Creek at elevations above 150 meters will generally extend over the C-b Tract. Typically subtraction of 150 meters from the local inversion heights and mixing heights observed at Piceance Creek Station AB20 is required to obtain heights above the C-b Tract. Very few mixing heights observed at Station AB20 exceed 150 meters.

6. Temperature-Altitude profiles obtained from pibal trajectories indicated inversion heights that were in agreement with acoustic radar inversion heights.

7. Temperature-altitude profiles obtained by either single or double theodolite are adequate for upper air temperature measurements over the C-b Tract.

8. The atmosphere is typically unstable between hours 0900 and 1900. Nighttime is typically stable in summer and fall and neutral in the winter and spring.

9. Tracer test meteorological data confirm the near-surface channelization of winds over the C-b Tract to flow downvalley during early morning under stable conditions.

10. Tracer tests show higher concentrations of pollutant gases can be expected to occur along Piceance Creek to the north and west of the C-b Tract under stable conditions.

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7.0. NOISE

7.1 Introduction and Scope

The environmental noise program conducted during baseline was not required under the lease but was requested by the Area Oil Shale Supervisor. General background noise levels were sought on the Tract and surrounding vicinity prior to Tract development. Monitoring of those levels was reinitiated in February 1978, at the three sites shown in Figure 7.1.1-1 to determine the effects of Tract development on noise levels.

7.2 Environmental Noise

It is to be noted that occupational noise exposure is treated in Chapter 10.0 of this report. Aspects of environmental noise treated here deal with traffic and Tract-generated noise levels.

7.2.1 Traffic Noise

7.2.1.1 Scope and Rationale

The traffic noise study was originated during baseline. Measurements were made one working day per month for approximately one hour at each of 14 locations over a 14-month span starting in September 1975. Measured noise levels (A weightings) above background at two locations along Piceance Creek Road were always made in the presence of passing vehicles. The noise analysis contained in the final baseline report indicated an average level at a station on Piceance Creek Road near Hunter Creek to be 53dbA which was exceeded ten percent of the time.

On the basis of low noise levels existing during baseline as indicated in the final baseline report, it was felt that continued discrete measurements were warranted at only two of the original 14 locations. Stations NA02 and NA09 are located to indicate traffic noise levels associated with development.

7.2.1.2 Objectives

To measure potential increases in traffic noise levels due to development.

7.2.1.3 Experimental Design

Discrete traffic noise measurements are made one day per week during the morning shift change in the presence of passing vehicles at Stations NA02 and NA09 (Figure 7.1.1-1) along Piceance Creek Road and on the access road at the Tract boundary, respectively. The General Radio 1565 Sound Level Meter (SLM) is used to measure peak noise levels at A weightings. Background levels are obtained the same day at A, B, and C weightings.

FIGURE 7.1.1-1

NOISE ENVIRONMENTAL MONITORING NETWORK

● TRAFFIC NOISE STATION - SHIFT CHANGE - 1 DAY/ WEEK

■ TRACT NOISE SURVEILLANCE - CONTINUOUS - EVERY 6th DAY

7.2.1.4 Method of Analysis

At each of the two stations, peak noise levels measured weekly are averaged once each month.

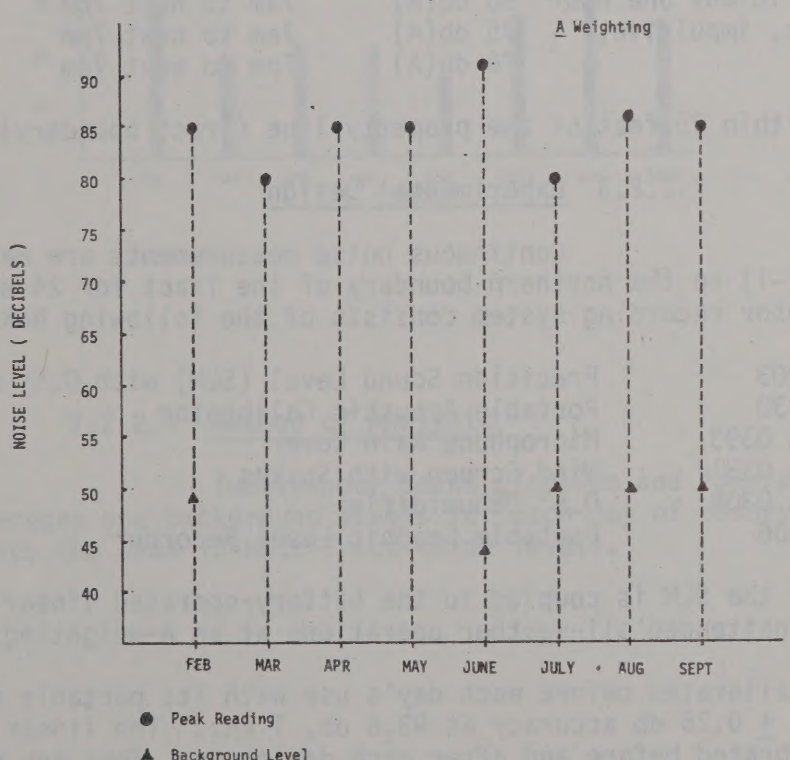
7.2.1.5 Results and Discussion

Figure 7.2.1-1 shows a time plot of peak traffic noise levels and background levels for the C-b Tract. The highest noise level of 91 dbA occurred on June 30, 1978 at Station NA02 from a passing semi-trailer truck; the background at that time was 44 dbA. The peak noise level indicated in the final baseline report was 83 dbA from a road scraper in July 1976. Seventy-five percent of the 1978 monthly peaks exceeded this level; on the average, the 1978 monthly peaks are 9 db higher than those during baseline.

FIGURE 7.2.1-1

TRACT C-b PEAK TRAFFIC NOISE READINGS

(1978)



7.2.1.6 Conclusions

Monthly peak noise levels and background levels during 1978 exceed those of the baseline period by an average of 9 dbA. It is felt that this increase is probably development related.

7.2.2 Tract Noise

7.2.2.1 Scope and Rationale

During the ancillary phase of development nearly all activity occurs near the northern boundary of the Tract. Thus a noise monitoring site in the vicinity of operations is most appropriate for monitoring noise levels on Tract due to ancillary development.

7.2.2.2 Objectives

The objectives of the Tract noise study are 1) to evaluate increases in Tract noise due to Tract development, and 2) to demonstrate compliance with State noise regulations.

State noise standards for an industrial zone are as follows in terms of maximum allowable noise levels:

Steady:	80 db(A)	7am to next 7pm
	75 db(A)	7pm to next 7am
15 min. in any one hour	90 db(A)	7am to next 7pm
Periodic, impulsive,	75 db(A)	7am to next 7pm
shrill	70 db(A)	7pm to next 7am

They apply within 25 feet of the property line (Tract boundary).

7.2.2.3 Experimental Design

Continuous noise measurements are made at Station NB15 (Figure 7.1.1-1) on the northern boundary of the Tract for 24 hours every sixth day. The sensor recording system consists of the following B&K instruments:

Model 2203	Precision Sound Level (SLM) with 0.5" microphone
Model 4230	Portable Acoustic Calibrator
Model UA 0393	Microphone Rain Cover
Model UA 0381	Wind Screen with Spikes
Model UA 0308	0.5" Dehumidifier
Model 2306	Portable Graphic Level Recorder

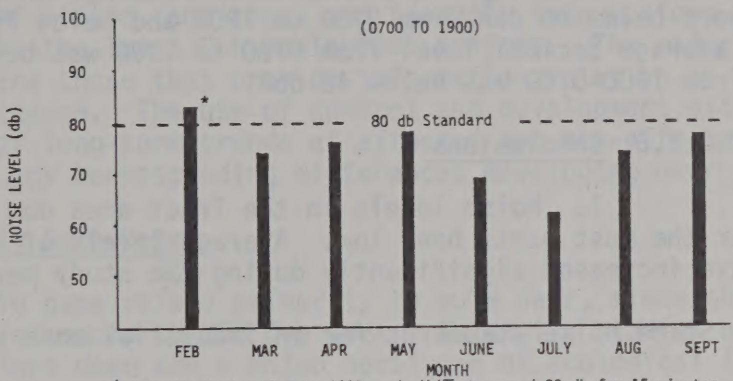
In this model the SLM is coupled to the battery-operated linear recorder for 24-hours of unattended all-weather operations at an A-weighting.

The SLM is calibrated before each day's use with its portable acoustic calibrator to ± 0.25 db accuracy at 93.6 db, 1 kHz. The linear recorder for a range is calibrated before and after each day's use. Thus any drifts are readily apparent. Time references are annotated before and after operation.

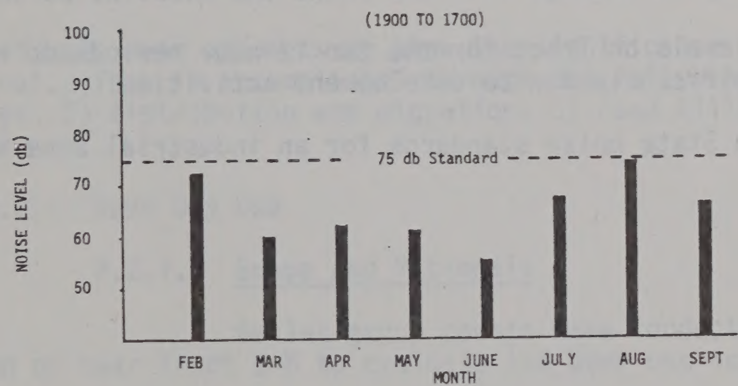
FIGURE 7.2.2-1

TRACT C-b NOISE STANDARDS COMPLIANCE

SITE NB15 - 12 HOUR PEAK NOISE READINGS (db) FOR 1978



* On 2-13-78 for 0700 to 1900 peak did not exceed 90 db for 15 minutes in any hour.



7.2.2.4 Method of Analysis

Twelve-hour peaks (7am-7pm and 7pm-7am) are reported along with averages and background levels for each day of observations. Figure 7.2.2-1 presents the peak 12-hour Tract noise levels.

7.2.2.5 Results and Discussion

The peak Tract noise level reading of 83 decibels occurred on the first day of monitoring in February 1978; that peak did not exceed 90 dbA for 15 minutes in any hour. All other readings through September 1978 at site NB15 were below 80 dbA from 0700 to 1900 and below 75 dbA from 1900 to 0700. The average decibel level from 0700 to 1900 was below 45 dbA while the average from 1900-0700 was below 42 dbA.

7.2.2.6 Conclusions

1. Noise levels in the Tract area due to development activities have, for the most part, been low. Average levels of neither 12-hour period appear to have increased significantly during the study period.

2. Compliance with State noise standards for an industrial zone was achieved.

7.3 Overall Conclusions

1. Peak noise levels and background levels along the Tract boundary increased by an average of 9 dbA since the baseline period.

2. Average noise levels on Tract for the two 12-hour periods do not appear to have increased significantly due to development activities.

3. Compliance with State noise standards for an industrial zone was achieved.

8.0 BIOLOGY

8.1 Introduction and Scope

The goal of the biological monitoring program is to continue evaluation of biotic conditions and identify interactions with abiotic conditions in the Tract C-b ecological systems. The majority of monitoring parameters are those that provide information relative to early warning signals of change. The use of control and development sites permits the monitoring of long-term trends at affected and non-affected sites, and the analysis of any corresponding differences developing over time at these sites.

8.2 Big Game-Deer

Big game refers primarily to mule deer, since they are the only large mammals common to the C-b area. Intensive studies of mule deer are justified since deer are a major herbivore of ecological importance, and a game species of economic importance. In addition, they are vulnerable to impact from development activities, road kill, and increased hunting pressure. Study transects and sample sizes are based on adequate samples obtained during baseline.

Monitoring of mule deer attempts to show the significance of Tract C-b to their survival. This is accomplished through the following variables: 1) deer-use days, 2) distribution and migration, 3) road kills, 4) mortality, and 5) age class.

8.2.1 Deer Day Use

8.2.1.1 Scope and Rationale

Pellet group counts were conducted on 27 permanent transects on or near Tract C-b to evaluate the deer use in the area.

8.2.1.2 Objectives

The objectives were to use deer pellet group data to check to see if significant differences existed among the sizes and distributions of local deer concentrations at selected sites on a year-to-year basis.

8.2.1.3 Experimental Design

Two habitat types were sampled; pinyon-juniper woodland and chained pinyon-juniper. Fifteen transects were located in the chained habitat type and twelve transects were located in the woodland. These same transects were used for lagomorph and browse utilization and production transects. Each transect consisted of 20 plots, with plots being 15 meters apart. Locations of the transects were well within the boundaries of the habitat type (avoiding habitat edges), and were positioned such that comparisons

could be made of development vs. control areas, i.e., oil shale vs. non-oil shale effects. Some of these transects were placed to the north and west of the Tract to detect shifts in distribution due to development-related activities. There were 9 developmental and 18 control transects. Stations using the symbol BA are identified on the jacket map. Data concerning deer pellet-group distributions and densities were obtained by counting pellet-groups along these twenty-seven transects. Pellets were swept from plots during the fall of 1977 and counts were made the following spring.

Fifteen new transects were added to the original twelve that were established during the interim-monitoring program: nine in the chained rangeland habitat on Big Jimmy ridge; and six in the pinyon-juniper habitat north of Piceance Creek. Both of these locations are just outside Tract C-b boundaries.

The pellet-group data obtained from all twenty-seven transects are here considered to be baseline data. Construction operations, which began during the past year, are assumed to have caused no appreciable impacts to deer in those areas where transects are located. Transect BA16, however, is near the main access road that was constructed during the spring of 1978. Construction activities along this right-of-way have influenced pellet count data on one or two of the 20 plots that make up the transect, but examination of these data do not suggest this to be the case.

Since future deer pellet counts are likely to be markedly influenced at certain transect locations due to development, the relative differences which exist among the twenty-seven transects at this final baseline stage are of considerable importance. This, and all previous baseline information on pellet-group distributions represent the final pattern, or array of data points, from which future departures of a significant nature will be looked upon as due to development-related impacts.

8.2.1.4 Method of Analysis

Results were evaluated using single factor analysis of variance (ANOVA) and Student-Newman-Keuls (SNK) multiple range testing.

8.2.1.5 Results and Discussion

The results of pellet-group counts for the 1977-78 period (Tables A8.2.1-1a to 1d) are presented as individual estimates for density for each of the twenty-seven transects and as combined values for clusters of transects. With regard to the grouping of certain transects, it may be appropriate in future evaluations to combine different clusters because of development activities in locations not anticipated at this time. Some amount of combining will probably always be needed in order to achieve sampling adequacy.

The apparent differences in the three sets of combined values for the chained rangeland habitat (Tables A8.2.1-1a and 1c) were evaluated using single factor analysis of variance (ANOVA) and Student-Newman-Keuls (SNK) multiple range testing. Significant differences (at the 95 percent level) were found to exist between the two combined values for the chained pinyon-juniper transects on the tract, namely, the mean density estimates of 288 vs. 437 pellet-groups per acre (transects BA17, 18, 25 vs. transects BA20, 21, 25)(Table A8.2.1-1c); and between the combined value of 398 per acre obtained for Big Jimmy ridge (Table

A8.2.1-1c) and the 288 mean value for the tract (Table A8.2.1-1a). The 437 and 398 values obtained for the tract and for Big Jimmy ridge respectively were not found to be significantly different. Differences in pellet-group densities among the four combined values for the pinyon-juniper habitat (Tables A8.2.1-1b and A8.2.1-1d) were also subjected to ANOVA and SNK testing. All combinations of three values (105, 357, and 238 pellet-groups per acre) (transects BA10-12; BA13-15, and BA19, 26, 27) were found to be significantly different at the 95 percent level. Only the differences between the two combined values for the tract (238 and 198) (transects BA16, 22, 24) were not found to be significant.

In terms of trend evaluations it is important to note that the highest pellet-group density estimates obtained over the past two years occurred on transects BA20 and BA21, which are located near Sorghum Gulch. This consistency is demonstrated in Figure 8.2.1-1, which also shows a consistent pattern of relative densities for all transects when comparing the two years. This apparent correlation is, in fact, statistically significant (γ=0.86, P=0.001).

The decline in the density estimates during the second year, 1977-78, represents a mean drop of 48 percent. This should not be taken as suggesting there were 48 percent fewer deer during the 1977-78 period, since an investigator bias is known to have existed during the 1976-77 period. This bias, however, is believed to have uniformly inflated the 1976-77 estimates, and not to have affected relative differences among transects.

Direct comparisons of pellet-group data over the past two years with data from the first two years of baseline study (C-b Final Environmental Baseline Report 1974-76) is not possible, since transect locations were changed for the development monitoring program.

Data from pellet-group distribution and density studies on transect locations which have been operative over the past two years have indicated very similar patterns of habitat use.

8.2.2 Distribution and Migration

8.2.2.1 Scope and Rationale

Deer road counts have proven useful for showing deer distributions along the Piceance Creek highway. The structured road count observations are repeatable, and provide a means of quantifying changes in relative abundance and distribution.

8.2.2.2 Objectives

The main objectives were to determine the seasonal and year-to-year movement patterns of deer.

8.2.2.3 Experimental Design

Weekly sampling was obtained beginning in mid-September and ending in May. The sample area was the 41-mile stretch of Highway 64. Times of migration were based on the occurrence and disappearance of deer in the meadows. Counts were made from a vehicle driving approximately 30 m.p.h. The counts were started one hour ± 15 minutes before dusk and the direction of travel was altered

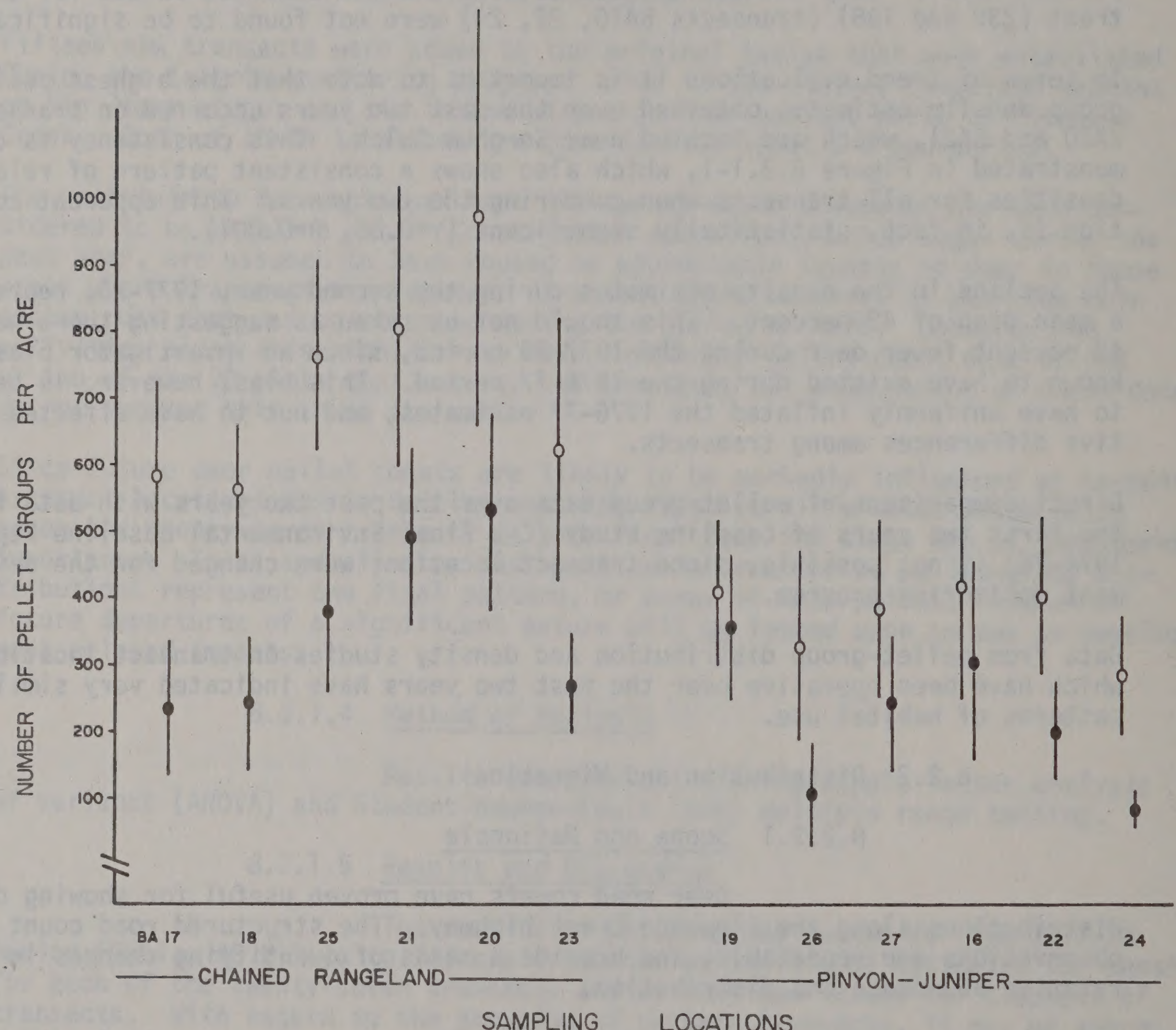


Fig. 8.2.1-1 Trends in pellet-group densities. Data shown are means ± 95 percent confidence intervals. Open circles are 1976-77 data; closed circles are 1977-78 data. Although pellet-group densities are lower the second year, the pattern of habitat use is significantly correlated (Y = 0.86; P = 0.001).

for consecutive (weekly) counts. The number of deer observed in each mile interval was recorded according to feeding locations on the slopes or in the meadows.

8.2.2.4 Method of Analysis

Histograms were prepared and compared to past years' data. The log-likelihood G test or other applicable nonparametric tests will be used if changes in observed distributions occur.

8.2.2.5 Results and Discussion

Twenty-nine road counts were conducted from September 1977 to May 1978 (Table A8.2.2-1). The length of road traveled during this period of investigation (41 miles) was expanded by six miles over the previous three years of study to include the section of road from Little Hills to the White River. A summary of the deer road counts is presented in Figure 8.2.2-1.

Due to seasonal differences in habitat use by deer and changes in vulnerability to road kill, Table A8.2.2-1 separates road count data into fall, winter, and spring periods. Locations along the road where fall road counts were particularly high include virtually the entire distance from mile 14 (Oldland's ranch) to mile 31 (Burk's ranch). From December through January, deer were not nearly as abundant near the road, although mile 22 (near Hunter Creek) retained a high count. During late winter and early spring, road counts were generally high over the entire 41 mile length of road. Very high counts occurred immediately west of the tract, between mile 20 (the main entrance road to Tract C-b) and mile 25 (near Rock School).

Trends in the number of deer observed along the six miles of road which approximately borders Tract C-b on the north will provide one means of evaluating impacts to deer due to construction and operation of the oil facility. It seems likely that disturbances and habitat loss on tract will eventually result in fewer deer observed especially from mile 17 to mile 20. No indications of this were apparent this past year, however.

The 1977 fall influx of deer into the Tract C-b area occurred during mid-October. Apparently during mid April of 1978 deer began to move to higher summer range. This pattern is similar to what was observed over the past three years of baseline study. As in previous years (1974,'75,'76) the majority of deer observed during the October deer counts were concentrated in the meadows between mile markers #15 to 20. In the spring, with the exception of high concentrations between mile 15 - 20, the deer have been fairly evenly distributed along the entire Piceance Creek highway. This was not the case in 1977. Large concentrations of deer were observed at the Rio Blanco Store end of the road. These slopes were free of snow before other south-facing slopes which may have attracted the deer. Deer distribution and migration will continue to be monitored and possible trends identified.

8.2.3 Roadkills

8.2.3.1 Scope and Rationale

Mule deer roadkill data were collected weekly to obtain

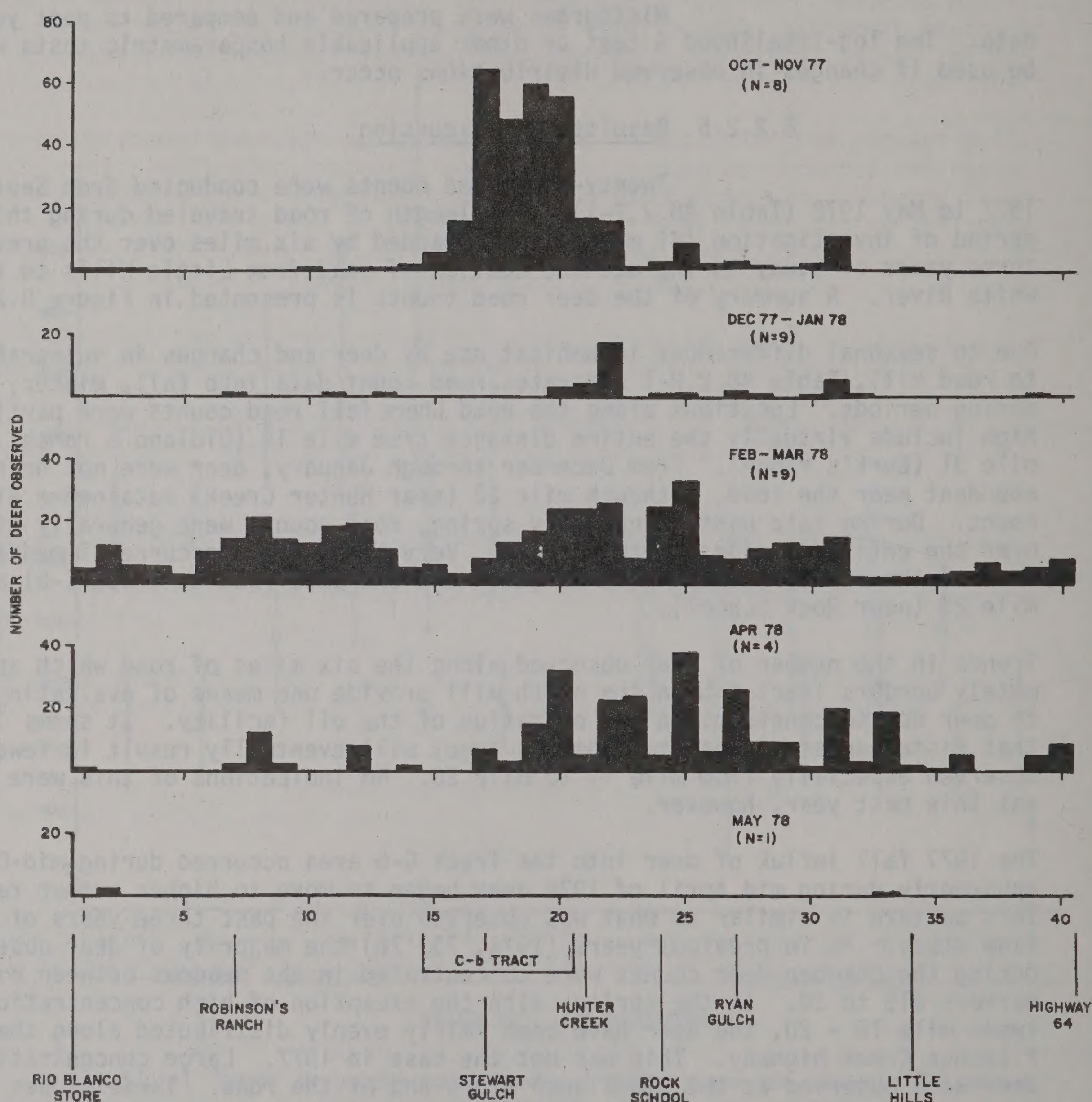


Fig. 8.2.2-1 — Summary of deer road counts for 1977-78. Heights of bars are means; sample size (N) are the number of road counts for the period.

information on the number of deer killed each year along the Piceance Creek highway.

8.2.3.2 Objectives

Roadkill data were collected to obtain an accurate fatality estimate and identify problem areas so mitigative measures could be taken, if necessary.

8.2.3.3 Experimental Design

Weekly roadkill data were collected from September 1977 into May 1978 at the same stations used for the deer road-count study. Dead deer were aged, sexed, and tagged. In addition, one ear was removed to insure that double counting did not occur.

8.2.3.4 Method of Analysis

When several years of data has been collected, monthly time series tabulations and non-parametric tests such as the log-likelihood G Test (Sokal & Rohlf 1967) will be used.

8.2.3.5 Results and Discussion

Roadkill data for 1977-1978 are presented in Table 8.2.3-1. The total roadkill along the Piceance Creek highway was 125 deer and one elk. This figure was derived by combining the information gathered by Division of Wildlife and Tract C-b personnel. At present, only general observations can be made. Most of the roadkills occurred in the fall and spring. This concurs with the deer movements; many deer are close to the highway during these times. Approximately 50% of the deer killed were fawns. Roadkill information will continue to be monitored closely to establish trends and possible mitigative measures. Cumulative roadkill approximates 1% of the total sited at these stations, noting that the same deer may be seen or recounted on subsequent weeks.

8.2.4 Mortality

8.2.4.1 Scope and Rationale

Baseline studies have shown winter kills to be largely restricted to two habitat types, lateral draws and bottomland sagebrush. Checking these areas each spring has helped in observing changes in the relative magnitude of deer mortality.

8.2.4.2 Objectives

The purpose of this study is to determine deer mortality in selected gulches.

8.2.4.3 Experimental Design

Sampling was done in the spring in 10 plots located in lateral draws and sagebrush gulches (Map in jacket). All dead deer were aged, sexed, and tagged with a metal tag stamped with the study year to date the deer carcasses. Either the skull or pelvic girdle was required to be with the

Table 8.2.3-1

MULE DEER ROADKILL SUMMARY (FALL 1977 TO SPRING 1978)

MILE INTERVAL	OCT.			NOV.			DEC.					JAN.				FEB.				MAR.					APR.				MAY	MILE INTERVAL
	24	27	28	3	10	17	1	8	15	22	29	5	12	19	25	3	9	16	23	2	9	16	23	30	6	13	20	27	4	
0 Rio Blanco Store																														0
1																														1
2			1		1																									2
3																														3
4																														4
5																			1											5
6																														6
7	1					1								1				1	4	3			1							7
8																				1										8
9					1																		1							9
10																*			2							1				10
11		1																			1		1							11
12		1																												12
13																													1	13
14																														14
15															1						1	1								15
16				1																					1					16
17		1		1	1								1			1				2				1						17
18	1																							1		1	1		1	18
19				1														1	1				1	1						19
20	1	1				1						1								1					1	1				20
21			1			1	1	1																	1	1				21
22					1																		1							22
23												1																		23
24 Rock School				1		1																								24
25																	1													25
26																														26
27												1																		27
28																			1											28
29				1																1			1							29
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35																										1				35
36													1																	36
37														2									1			1				37
38																														38
39															1			1	2											39
40													2								1									40
41 White River City																				1		1								41
TOTAL	3	4	2	5	4	7	1	1	0	0	0	5	6	3	2	2	2	3	11	10	5	2	7	3	3	6	1	0	2	

NOTE: Total Kill was 125 Deer. One Elk killed. This Figure was derived from combining DOW data with C-b data.

carcass before it was counted, i.e. just a leg or other bones did not constitute a carcass.

8.2.4.4 Method of Analysis

Non-parametric tests such as the log-likelihood G Test (Sokal & Rohlf 1967) will be used when several years of data have been collected on these mortality plots. Tabular presentations are used here.

8.2.4.5 Results and Conclusions

A comparison of deer mortality is presented in Table 8.2.4-1. Since several new draws have been added to the study, detailed analysis cannot be done. Possibly due to the mild winter, there were fewer dead deer per hectare than in previous years. Fawns comprised 80% of deer mortality found this year.

8.2.5 Age Class

8.2.5.1 Scope and Rationale

Estimating the composition of the deer herd in the fall facilitates evaluation of the magnitude of fawn mortality that has occurred during the spring and summer while deer were on summer range. Estimates taken in spring permit evaluation of fawn mortality that occurred while deer were on winter range in the C-b area.

8.2.5.2 Objectives

The main objective of the age class study was to determine fawn-to-adult ratios in the fall and spring.

8.2.5.3 Experimental Design

Sampling occurred in the fall and the spring. Sampling locations were situated in meadows immediately north of the Tract and major drainages within the study area. Counts were restricted to within five miles either side of Tract C-b and were conducted in November and in May. The observations took place during times of potential heavy concentrations. Animals were recorded as adults, fawns, or bucks. No attempt was made to recognize yearlings, and bucks were counted only when antlers were visible (otherwise, they were recorded as adults). The number of points on an antlered buck were noted when easily and quickly counted.

8.2.5.4 Method of Analysis

When sufficient data become available for year-to-year proportions to be established the T-test for proportions will be used to test the null hypothesis at the 0.10 level of significance. Data from this program, combined with data from the other Tract deer studies, tagged deer from the Division of Wildlife, and the roadkill simulation model will be used to further understand the dynamics of the deer herd on and surrounding Tract C-b. Interrelationships with other ecosystem elements may be evaluated through use of multiple time series techniques.

TABLE 8.2.4-1 DEER MORTALITY RESULTS

YEAR	HABITAT TYPE	NO. OF CARCASSES FOUND	HECTARES SAMPLED (ACRES)	CARCASSES/ HECTARE (ACRES)
1977-78	Sagebrush - Lateral draw	25	70.5 (174)	.355 (.144)
1976-77	Interim Monitoring Period - No Sampling			
1975-76	Lateral draws	8	7.25 (18)	1.10 (0.44)
1974-75	Lateral draws	11	7.25 (18)	1.52 (0.61)

8.2.5.5 Results and Conclusions

An estimate of the age-class composition of deer wintering near Tract C-b is given in Table 8.2.5-1. Results differ markedly from the previous three years in that the ratio of fawns to adults was higher in the spring than in the previous fall. One would have expected proportionately fewer fawns in the spring due to higher winter fawn mortality.

8.3 Medium-Sized Mammals

The medium-sized mammals are restricted to several species which are important within the Tract C-b ecosystem, coyotes and lagomorphs (cottontails and jackrabbits). Monitoring these animal groups will show important trends which will contribute to the understanding of predator and prey-species in the Tract C-b ecosystem.

8.3.1 Coyote Abundance

8.3.1.1 Scope and Rationale

Coyotes are of ecological significance because they are a major predator on Tract C-b. They are of political and economic interest to the public with both strongly negative and positive supporters. Collection of scent post data is important in understanding the C-b ecosystem, particularly predator/prey relationships.

8.3.1.2 Objectives

The objective of conducting coyote scent post surveys was to determine relative abundance of coyotes on or near the tract.

8.3.1.3 Experimental Design

The coyote scent post survey is based on the Linhard and Knowlton Method (1975), which is currently being used by the U.S. Fish and Wildlife Service. Sampling was done in September along 15 miles of road segments on or near the Tract. Scent stations along the transects were checked for the presence of tracks. Track surveys also yielded information on other species of mammals which may have inhabited or occasionally passed through the Tract. The stations were checked the morning following the setting of the traps.

8.3.1.4 Method of Analysis

A relative index of abundance was calculated as a visit frequency. Professional judgment also will be used to determine significant differences over time.

8.3.1.5 Results and Conclusions

Results of the September 1978 coyote scent stations survey (Table 8.3.1-1) are considerably lower than 1977 results. Indices of 50 and 130 were obtained for 1978 and 1977 respectively. Reasons for the apparent decline are unknown. The only removal of coyotes of which we

Table 8.2.5-1
Age class composition of mule deer wintering near Tract C-b

Date	Fawns	Does	Bucks	Adults	Fawns/ 100 Does	Bucks/ 100 Does	Fawns/ 100 Adults
15-23 Nov. 1977	85	107	28	135	79.4	26.2	63.0
4-7 Apr. 1978	68			104			65.0

Table 8.3.1-1
Results of coyote scent station survey, 1978.

Line	Location	No. of stations	No. of visits
1	Big Jimmy	25	2
2	SG-9	10	0
3	Scandard	10	0
4	SG-15	10	2
5	SG-11	10	0
6	Stewart ridge	15	0
7	Stewart valley	10	1
8	Bailey ridge	10	0

$$\text{Index of abundance} = \frac{\text{No. of visits}}{\text{No.of stations}} \times 1000 = 50$$

are aware took place in October 1978 when 42 coyotes were trapped on the Oldland property north and east of Tract C-b.

No new species of medium-sized mammals were identified during the past year of field study.

8.3.2 Lagomorphs

8.3.2.1 Scope and Rationale

Cottontails and jackrabbits provide an important prey base for raptorial birds and coyotes. The cottontail is classified as a game species, but presently it is of little economic value in the vicinity of Tract C-b; however, at some future date its status could change. The lagomorph population estimates are based on relative abundance data collected from strip transects.

8.3.2.2 Objectives

The objectives were to determine the relative abundance of lagomorphs on or near Tract C-b.

8.3.2.3 Experimental Design

Relative abundance of cottontail rabbits was established along the twenty-seven transects used for mule deer pellet-group counts. The study was expanded to include Big Jimmy Ridge. The number of plots sampled were 20 plots/transect.

8.3.2.4 Method of Analysis

A relative index of abundance was calculated as a visit frequency.

8.3.2.5 Results and Conclusions

The results of this study are considered to be most valuable for comparing relative differences among years, rather than for comparisons of differences among transects. Trend evaluations are not feasible at this time, however, since data for the twenty-seven transects being used are only available for the 1977-78 period. (Table 8.3.2-1). General observations between this year's and previous year's data show that cottontail abundance was slightly higher in the pinyon-juniper woodlands compared to chained pinyon-juniper. Field observations this fall tended to show that the cottontail population was higher in fall 1978 than in fall 1977.

8.4 Small Mammals

8.4.1 Species Composition and Abundance

8.4.1.1 Scope and Rationale

Small mammals are important to monitor because they are both a prey base for predators and a major primary consumer. Monitoring

Table 8.3.2-1
Relative abundance of cottontail rabbits, 1977-78. Each transect consists of twenty 0.01 acre plots.

Transect: Monitoring notation	Transect: Baseline notation	Habitat and location	Relative abundance*
BA 01	CH-C-12	Chained, Big Jimmy	55
BA 02	CH-C-11	"	15
BA 03	CH-C-10	"	30
BA 04	CH-C-9	"	45
BA 05	CH-C-8	"	90
BA 06	CH-C-7	"	55
BA 07	CH-C-6	"	80
BA 08	CH-C-5	"	65
BA 09	CH-C-4	"	80
BA 17	CH-C-1	Chained, Tract	35
BA 18	CH-C-2	"	45
BA 25	CH-C-3	"	60
BA 21	CH-T-1	"	70
BA 20	CH-T-2	"	35
BA 23	CH-T-3	"	42
BA 19	PJ-C-1	Pinyon-juniper, Tract	40
BA 26	PJ-C-2	"	70
BA 27	PJ-C-3	"	90
BA 16	PJ-T-1	"	35
BA 22	PJ-T-2	"	58
BA 24	PJ-T-3	"	35
BA 13	PJ-C-4	P-J, north of Piceance Crk.	85
BA 14	PJ-C-5	"	60
BA 15	PJ-C-6	"	15
BA 10	PJ-T-4	"	75
BA 11	PJ-T-5	"	75
BA 12	PJ-T-6	"	75

* Relative abundance is calculated as a percent frequency ((No. of plots with fresh pellets present ÷ No. of plots sampled) x 100).

changes in selected small mammal parameters will aid in assessing potential effects of pollutants before populations of larger animals are greatly affected.

8.4.1.2 Objectives

The objectives of monitoring small mammals on Tract C-b were to determine small mammal species composition, reproductive conditions, age classes and relative abundances and to see how the development of Tract C-b is affecting this population as manifested by these parameters.

8.4.1.3 Experimental Design

Small mammal live trapping was conducted in three habitat types: pinyon-juniper woodland, chained rangeland, and agricultural meadow. The agricultural meadow was divided into control and experimental (hereafter referred to as "development") plots. Linear transects consisting of 25 traps spaced at 10m were placed as follows: four transects in each of the two meadow locations; two transects each in the pinyon-juniper and chained rangeland habitats. Trapping occurred for three consecutive nights (omitting rainy nights) during June and August. After each night all traps were repositioned using new transect locations.

8.4.1.4 Method of Analysis

Indices of relative abundance were calculated to allow comparisons between the data.

8.4.1.5 Results and Conclusions

Small mammal trapping results for the June and August periods (Table 8.4.1-1) are presented as indices of relative abundance in order that differences can be directly compared. Future trend evaluations will continue to use these indices to facilitate descriptions of yearly fluctuations and changes suggestive of impacts.

The small mammal results obtained this past year are in no way unusual compared to prior studies conducted during the first two years of baseline study. The deer mouse (Peromyscus maniculatus) was, as in previous years, the most abundant small mammal species in the habitat types trapped on Tract C-b. Of most interest in subsequent years will be changes in species diversity and relative abundance between control and development locations in the agricultural meadows.

8.5 Avifauna

A wide variety of birds exist on Tract C-b and the surrounding area. Avifauna were monitored to determine potential effects on habitat disturbance.

8.5.1 Songbird Relative Abundance and Species Composition

8.5.1.1 Scope and Rationale

Songbirds were monitored during their breeding season to determine potential development effects. It is anticipated that habitat

Table 8.4.1-1

Relative abundance of small mammals, 1978.*

Common name Scientific name	TRAPPING LOCATION: Meadow, control plot JUN	Meadow, control plot AUG	Meadow, developmental plot JUN	Meadow, developmental plot AUG	Pinyon-juniper JUN	Pinyon-juniper AUG	Chained rangeland JUN	Chained rangeland AUG
Deer mouse *Peromyscus maniculatus*	3.7	29.7	4.0	22.3	18.7	30.7	24.7	28.7
Montane vole *Microtus montanus*	0	1.3	0.3	0.7	0	0	0	0
Western jumping mouse *Zapus princeps*	0	1.3	0.3	0.7	0	0	0	0
Least chipmunk *Eutamias minimus*	0	0	0	0.3	0.7	1.3	8.7	12.0
Uinta chipmunk *Eutamias umbrinus*	0	0	0	0	2.7	0.7	0.7	1.3
Golden-mantled ground squirrel *Spermophilus lateralis*	0	0	0	0.7	0	0	1.3	0
Bushy-tailed woodrat *Neotoma cinerea*	0	0	0	0	0	0	0	0.7

* Relative abundance is calculated as a percent frequency ((No. of captures ÷ number of trap-nights) x 100). In the meadow locations, 100 traps were set for three nights (300 trap-nights); in the pinyon-juniper and chained locations, 50 traps each were set for three nights (150 trap-nights).

disturbance and increased human activity may affect population densities and relative abundance of the more prominent species. Certain species may be more affected by man-made impacts than others.

8.5.1.2 Objectives

The objectives were to monitor population densities, species abundance and diversity of the songbirds in the area and compare this information to past years data.

8.5.1.3 Experimental Design

Monitoring of avifauna for 1978 occurred between May 23, 1978 and June 28, 1978. Monitoring efforts were consistent with previous interim sample periods in that two transects in Pinyon-juniper woodland and two transects in chained Pinyon-juniper rangeland were censused. Each transect was sampled in quadruplicate; twice at the beginning of the breeding season, once in the middle and once at the end of the season. One transect in each habitat type (Transects 1 and 4) is located in an area which will not be disturbed by shale oil development. The remaining two transects (2, 3) are sample areas within each habitat where some disturbance from oil shale development is anticipated. All transects are 800 meters long and are permanently marked with steel rebar stakes and flagging. The method employed for censusing was the strip transect method as described by Emlen (1971) with slight modifications. This method provides data from which quantitative estimates of density of songbird and songbird-like species can be calculated.

8.5.1.4 Methods of Analysis

The population density estimates for species observed on strip transects were determined by one of the three methods described by Emlen (1971) which depended on the conspicuousness of the species to the observer. Since the validity of any of these methods varied for different species, professional judgment, based on experience with the conspicuousness of various species within different habitats during different seasons, was used in selecting the best density estimator. The Shannon-Weiner calculations (Pielou 1966) were used to compute indices of species diversity (H'), maximum diversity (H'max) and equitability (J) for each habitat sampled by strip transect procedures. Symbols are defined in Table 8.5.1-1. After three years of monitoring, statistical analysis of variance will be applied to replicated census data from each of the plots to estimate variations within, as well as between sampling plots.

8.5.1.5 Results and Conclusions

Table 8.5.1-1 presents diversity indices calculated for each transect. As with previous sample periods, the pinyon-juniper woodland exhibited greater avain diversity than the chained pinyon-juniper rangeland. Brewer's sparrows and green-tailed towhees were the most abundant species in chained pinyon-juniper rangeland, while the bustit, black-throated gray warbler were common in pinyon-juniper woodland.

Table A8.5.1-1 in the appendix lists bird species observed during the spring 1978 census. Included in Table A8.5.1-1 are species that were observed but were not included in the quantitative analysis because they were not observed within a strip census corridor or because specific habits of species, such as

TABLE 8.5.1-1 AVIFAUNA

SHANNON-WIENER DIVERSITY INDICES (H'), UNBIASED ESTIMATES OF H' (E(H')), VARIANCE OF H' (var(H')), MAXIMUM EXPECTED VALUE OF H' (H'(max)), AND EQUITABILITY (J), FOR AVIFAUNA TRANSECTS AT TRACT C-b DURING SPRING SAMPLE PERIOD, 1977, 1978.

TRANSECT	VEGETATION TYPE	YEAR	H'	E(H')	var(H')	H'(max)	J
1	Chained Pinyon-Juniper Rangeland - Control	1977	1.494	1.454	0.009	2.079	0.718
		1978	1.665	1.634	0.007	2.398	0.694
2	Pinyon-Juniper Woodland - Developmental	1977	2.469	2.432	0.003	2.890	0.854
		1978	2.398	2.350	0.004	2.708	0.886
3	Chained Pinyon-Juniper Woodland - Developmental	1977	1.950	1.895	0.004	2.197	0.888
		1978	1.885	1.868	0.003	2.398	0.786
4	Pinyon-Juniper Woodland - Control	1977	2.740	2.709	0.001	2.944	0.931
		1978	2.545	2.522	0.002	2.890	0.881

DEFINITIONS FOR SHANNON-WIENER CALCULATION VARIABLES

H'=Diversity. H' is an estimate of the diversity of the total population of individuals in a species pool. It is dependent on both the number of species in a collection and the relative abundance of each species (or evenness). Diversity can be thought of as measuring the uncertainty of predicting the species of an individual drawn at random from the entire population of individuals of several species. This uncertainty, or diversity, of a community can be increased either by increasing the number of species or by evening out the distribution of individuals among species. An H' value of zero is obtained when all individuals belong to the same species. Maximum values are obtained when all individuals belong to different species.

E (H') = The expected or unbiased estimate of H'. An estimate of diversity (H') corrected for bias associated with sample size.

Var (H') = Variance of H'. Variance is a measure of dispersion. It is defined to be the average of the square of the deviations of a set of measurements about their mean.

H' (max) = The maximum value of H'. An estimate of maximum possible species diversity for a given number of species and individuals.

J = Equitabliity or Evenness. The distribution of individuals among species is referred to as equitability. As discussed under diversity, evenness is a component of diversity. Large values of J are indicative of a rather even distribution of densities among species, while low values suggest dominance by a few species. J is expressed as the ratio of H' over H' max (H'/H'max).

red-tailed hawk and common raven, rendered them unsuitable for this type of quantitative analysis (Emlen 1971). Tables A8.5.1-2a through -2d summarized strip transect results and estimates of relative abundance and density for each transect.

8.5.2 Upland Gamebirds - Mourning Dove Relative Abundance

8.5.2.1 Scope and Rationale

Field observations during the baseline data accumulation program indicated that sage grouse and blue grouse populations are so sparse on and near the Tract that no reasonable monitoring program for them can be designed to determine changes over time; thus, a monitoring program for them is not warranted. The mourning dove is the only upland gamebird present in sufficient numbers to be monitored.

8.5.2.2 Objectives

The objective was to monitor the mourning dove populations to see if development of Tract C-b has affected their relative abundance.

8.5.2.3 Experimental Design

Methods used were identical to those used for songbirds. Throughout the year gamebirds observed were recorded on Wildlife Observation Reports.

8.5.2.4 Method of Analysis

The data were analyzed in the identical manner described for analyzing the relative abundance for the songbird-like population parameter.

8.5.2.5 Results and Conclusions

Table 8.5.2-1 shows mourning dove estimates on the four avifauna transects on Tract C-b. Mourning doves were not found on the developmental transects during the sampling periods. There are not enough data to make any conclusions at this time. However, the mourning dove transects will continue to be monitored closely next year to see if this was a one-year occurrence or if mourning doves have moved out of the developmental areas.

Table 8.5.2-1

Mourning Dove Estimates at Tract C-b for Spring Sample Period, 1978

Transect	Obs.	Coeff. Det.	Basal Adj.	Density /ha	% Relative Abundance
Chained Pinyon-Juniper (Control)	1	1.0	*	0.02	0.9
Pinyon-Juniper (Developmental)	0	-	-	-	-
Chained Pinyon-Juniper (Developmental)	0	-	-	-	-
Pinyon-Juniper (Control)	5	0.74	*	0.17	4.2

Other gamebirds seen on tract during 1978 included one sage grouse by the meteorological tower in October and one blue grouse in Sorghum Draw in December. Both birds were only observed one time. These birds were probably crossing Tract C-b to another location.

8.5.3 Raptor Activity

8.5.3.1 Scope and Rationale

Raptor activity was monitored on Tract C-b on a continuing basis because of the importance of raptors in the food chain, their apparent vulnerability to man's activities, their political value as threatened or endangered species, and their aesthetic appeal.

8.5.3.2 Objectives

The main objective was to detect changes in raptor utilization on or near Tract C-b.

8.5.3.3 Experimental Design

Trends in utilization of Tract C-b and immediately contiguous habitats by raptors were established for the breeding season by determining the percent of known nest sites which were occupied by nesting pairs and comparing this data with data obtained during the baseline period and following years. Nest occupancy checks were made annually during mid-March (great horned owls and ravens), late-April (red-tailed hawks, eagles), and early-June (accipiters, American kestrels, harriers). Throughout the year, any raptor sightings by the field biologists within the study boundary were recorded.

8.5.3.4 Methods of Analysis

Data analysis of nest occupancy was by professional judgment.

8.5.3.5 Results and Conclusions

Raptor nesting records for 1978 and the two previous years are listed in Table 8.5.3-1. Six active nests were located during the April sampling period, comprising of four red-tailed hawks and two great horned owl nests. Only three of the nests were active during the June census. All the nests contained young.

In addition to the nesting raptors, other raptors observed during 1978 on or near Tract C-b included: bald eagle, golden eagle, prairie falcon, Cooper's hawk, sharp shinned hawk, American kestrel, turkey vulture, common raven and marsh hawk. Most of these raptors were observed in only small numbers.

8.6 Aquatic Ecology

The variables of the aquatic program to be sampled through the environmental monitoring program are benthos, periphyton, and water quality. Because aquatic ecosystems could be secondarily affected by mining and development on tract, aquatic monitoring is essential. Benthos and periphyton are "indicators" of a significant change in stream characteristics downstream from oil shale development. The specific changes should be apparent in water quality parameters. In addition to the quarterly water analysis, daily water samples will be collected and stored for a month after periphyton are sampled and analyzed. If significant differences are noted in the primary indicators (periphyton and benthos) these daily samples can be analyzed to determine if changes in aquatic biota are due to a change in water quality. The daily water sampling will reflect rapid changes in water quality that may be short lived but still have an effect on the aquatic biota. Statistical comparisons to baseline data would show alterations of baseline conditions and indicate, through correlation coefficients, the severity of the impact so that timely corrections of detrimental conditions could be made.

8.6.1 Benthos

8.6.1.1 Scope and Rationale

The benthic species are important as lower-level consumers in the stream community as well as providing food for carnivorous species. They can be significant indicators of changes in the aquatic habitat. There are a number of organisms indicative of good or poor water quality conditions and qualitative data will give indication of changes in water quality.

8.6.1.2 Objectives

To infer water quality from invertebrate species present.

8.6.1.3 Experimental Design

The method used during the baseline and interim studies is continued during Development Monitoring. The surber sampler is used to make benthic collections at control and development stations on Piceance and Willow Creeks by the U.S.G.S. The following aquatic sampling stations established during the baseline period are used: WU07 (control) and WU61 and WU58

TABLE 8.5.3-1 RAPTOR NESTING RECORD

Nest No.	Species	Status 1976	Status 1977 April	Status 1977 June	Status 1978 April	Status 1978 June
1	Unknown	I	I	I	I	I
2	Unknown	I	I	I	I	I
3	Unknown	I	I	I	I	I
4	Red-tailed Hawk	E or Y	I	I	I	I
5	Unknown	I	I	I	I	I
5a	Common Raven	-	-	E or Y	I	I
6	Red-tailed Hawk	E	I	2Y	I	I
7	Red-tailed Hawk	I	I	-	E	I
8	Red-tailed Hawk	4Y	I	I	E	I
9	Common Raven	I	I	I	I	I
10	Red-tailed Hawk	I	I	I	I	I
11	Could not Locate					
12	Red-tailed Hawk	I	I	I	E	1Y
13	Red-tailed Hawk	I	I	I	I	I
14	Unknown	I	I	I	I	I
15	Unknown	I	I	I	I	I
16	Great Horned Owl	I	I	I	E	2Y
17	Great Horned Owl	I	I	I	I	I
18	Red-tailed Hawk	I	I	I	I	I
19	Great Horned Owl	1Y	I	I	I	I
20	Not on Map					
21	Not on Map					
22	Unknown	I	I	I	I	I
23	Not on Map					
24	Red-tailed Hawk	I	I	I	I	I
25	Great Horned Owl	I	I	I	I	I
26	Unknown	I	I	I	I	I
27	Unknown	I	I	I	I	I
28	Golden Eagle	1Y	I	I	I	I
29	Unknown	I	I	I	I	I
30	Red-tailed Hawk	2Y	I	I	I	I
31	Unknown	I	I	I	I	I
32	Great Horned Owl	2Y	2Y	-	I	I
33	Unknown	I	I	I	I	I
34	Unknown	I	I	I	I	I
35	Unknown	I	I	I	I	I
36	Red-tailed Hawk	2Y	I	I	I	I
37	Unknown	I	I	I	I	I
38	Unknown	I	I	I	I	I
39	Golden Eagle	1Y	I	I	I	I
40	Unknown	I	I	I	I	I
41	Unknown	I	I	I	I	I
42	Unknown	I	I	I	I	I
42a	Red-tailed Hawk	-	-	2Y	I	I
43	Great Horned Owl	2Y	I	I	E	2Y
44	Unknown	I	I	I	I	I
45	Red-tailed Hawk	2Y	I	I	I	I
46 (new)	Red-tailed Hawk				E	I

Code:

I = inactive nest

E = adult bird observed in an incubating posture; presumed to be incubating eggs

(2)Y = number of young observed in the nest

E or Y = adult bird observed in an incubating posture; due to time of year, assumed to be either incubating eggs or brooding very young chicks.

(development stations). (See jacket map for locations) Information from U.S.G.S. data will be used for correlations with data collected during environmental monitoring. Sampling occurs monthly and is coordinated with surface water sampling. During winter months benthos studies are discontinued due to inaccessibility dependent on weather conditions as determined by the U.S.G.S.

8.6.1.4 Method of Analysis

The following hypotheses will be tested in this analysis after sufficient data become available:

H_0: No significant change exists in Benthos communities over time.

H_0: No significant difference exists in Benthos communities at control stations vs. developmental stations from baseline data, recognizing the differences during baseline.

Hypotheses will be tested utilizing Shannon-Weiner diversity indices and T-test for proportions at $\alpha = 0.10$ level.

For each sampling period, the data will be summarized as follows: identify "ecologically important" taxa, determine percent relative abundance and diversity ($\overline{d}$) trends, compare these with previous sampling periods to ascertain seasonal trends, and compile a cumulative diversity ($\overline{d}$) table.

Each table will contain the following information:

1. Totals by order and/or family.
2. Totals by sample and station.
3. Percent relative abundance for (1) and (2).
4. Diversity ($\overline{d}$) for (1) and (2).
5. Maximum diversity ($\overline{d}$) for (1) and (2).
6. Equitability percent (e) for (1) and (2).
7. Number of taxa by sample, order, and/or family.

8.6.1.5 Results and Conclusions

C-b has not received benthic data from the Water Resources Division of U.S.G.S. for time period after May, 1978; therefore, limited results and conclusions are available at this time.

Table 8.6.1-1 summarizes the numbers of macroinvertebrates collected at six Piceance Creek stations during the two-year ecological baseline survey. (See Figure 8.6.1-1 for locations) The mean numbers of animals per square foot ranged from 25 at station PC-7 (Square-S Ranch site) to 79 at station PC-2 (just below Stewart Gulch site). Diptera, oligochaetes, and Ephemeroptera were, by far, the numerically dominant animals. Numerous studies of macroinvertebrates have shown that substratum and current velocity are important factors in determining the kinds and numbers present at particular sites.

The trend for numbers of kinds of invertebrates except aquatic worms to decrease at stations PC-6 (Hunter Gulch site) and PC-7 relative to upstream stations is probably more a reflection of increased amounts of silt and mud at these locations than to factors of temperature or water quality.

Table 8.6.1-1

Numbers of macroinvertebrates collected from Piceance Creek during 1974-1976

Taxon	P1	P2	P3	P5	P5a	P6	P7	Total
Ephemeroptera	319	240	402	303	190	116	36	1606
Odonata	0	0	0	0	0	0	4	4
Plecoptera	21	8	66	48	18	5	3	169
Trichoptera	12	5	12	23	2	1	0	55
Diptera	344	378	472	372	198	173	39	1976
Oligochaeta	240	515	118	114	209	275	245	1716
Other	68	42	68	63	28	17	2	288
Totals	1004	1188	1138	923	645	587	329	5814
Mean number/sample	67	79	76	62	54	42	25	

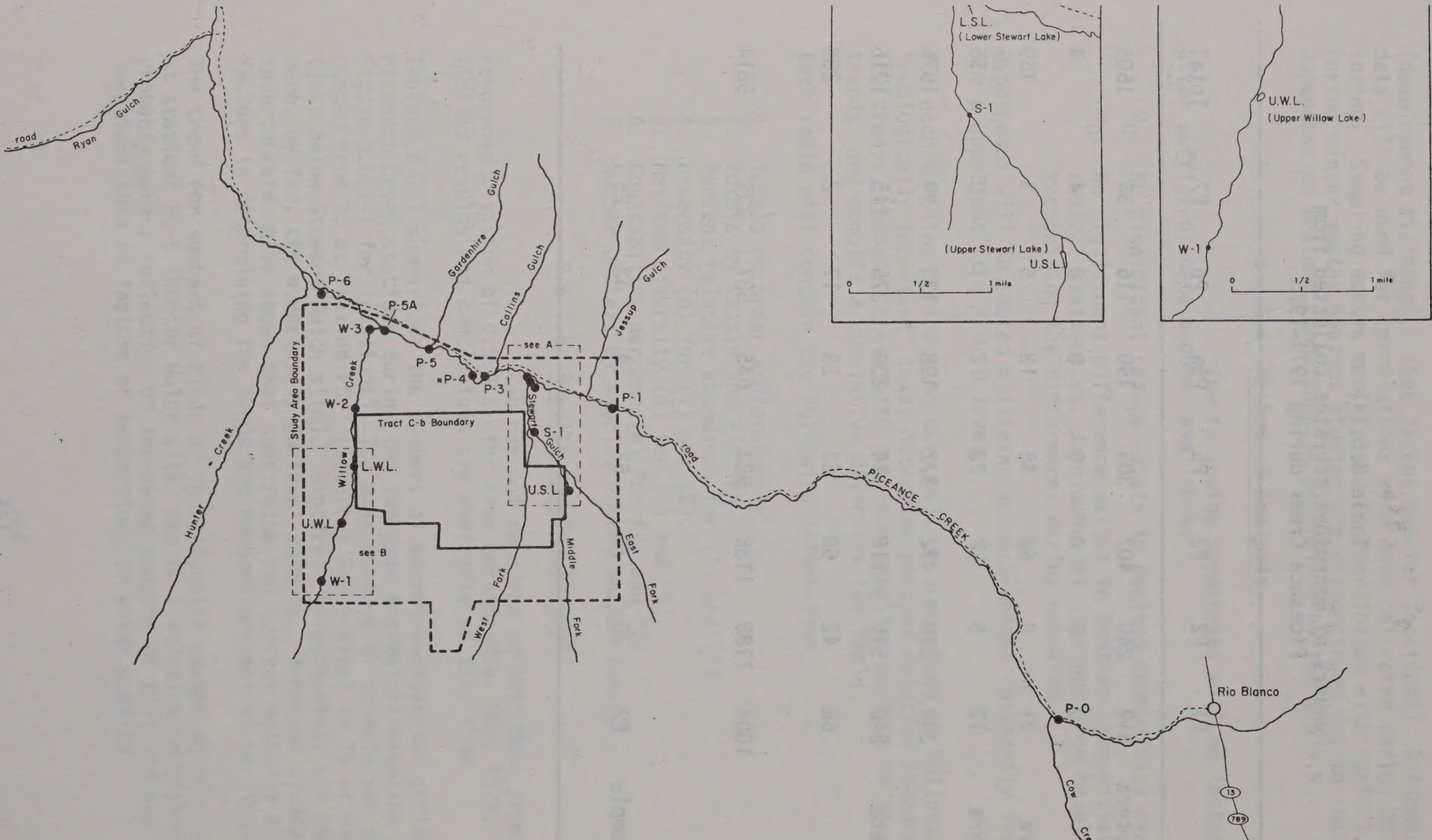

FIG. 8.6.1-1 AQUATIC SAMPLING STATIONS

NOTE:
Piceance Creek sites (P-1 thru P-7)
Willow Creek sites (W-1 thru W-3)
Stewart Creek sites (S-1, S-2)

* P-4 has been relocated to P-5A.

Everhart and May reported that the mean monthly numbers of benthic macroinvertebrates collected by them from four Piceance Creek stations in the period December 1968 through June 1969 was 144 individuals/ft^2 and from July through December 1969 it was 67/ft^2.

Numbers of macroinvertebrates in Piceance Creek samples were low; for example, eight samples from East Parachute Creek averaged 242 organisms/ft^2 and ten samples from West Parachute Creek averaged 474 individuals/ft^2 (Oil Shale Prototype Development Project, 1976). The same orders of insects that dominated Piceance Creek benthos were also dominant in Parachute Creek samples; however, oligochaetes were not an important part of the fauna there. Differences in type of substratum seem to be the chief casual factor in differences between Piceance Creek and Parachute Creek benthic faunas.

Not only were the numbers of macroinvertebrates in Piceance Creek small, but the individual organisms tend to be small. This is evident in the low fish food grade categories recorded during the two-year baseline survey. The volume of invertebrates (potential fish food) was usually in the poor grade (Lagler, 1956), i.e., less than 1 cc/ft^2. The average volume of macroinvertebrates reported by Everhart and May (1973) was less than 0.5 cc/ft^2.

Everhart and May's data are not strictly comparable to baseline because two of their invertebrate sampling stations were farther downstream than any of that program. However, their data are typical of results reported by other investigators, namely, a strong tendency for production of macroinvertebrates to be less downstream from Ryan Gulch than upstream from that point. The mean monthly biomass in Piceance Creek near its confluence with White River was from 1/12 to 1/40 that at their stations adjacent to Tract C-b.

8.6.2 Periphyton

8.6.2.1 Scope and Rationale

The periphyton communities are the major primary producers in the streams. They provide a major food source for benthic organisms and some fish species. They can respond very quickly to changes in water quality, and as such can be an important parameter for early detection of habitat degradation. Periphyton are stationary; therefore, they respond to changes in water quality at given locations. Locations are: Hunter Creek Gauging Station WU61, (PC-6 of Figure 8.6.1-1) and Stewart Gulch Gauging Station WU07 (PC-1).

8.6.2.2 Objective

The objective is to infer water quality and bioproductivity from species present.

8.6.2.3 Experimental Design

Collection of periphyton samples is accomplished monthly from two sites using artificial substrates (glass slides) which have been incubated in the water for at least 21 days. Sampling ran from May 1, 1978 to November 1, 1978, resulting in six collections. Six glass slides were incubated at each of the two locations. At the time of collection, three slides are collected at each location and placed in individual plastic containers

for biomass analysis (total of 6 slides). Also, three additional slides are collected in individual plastic containers and preserved with "M-3" preservative, a modified Lugol's solution, for taxonomic identification and enumeration (total of 6 slides).

The slides collected for biomass are oven dried at 105°C to constant weight. They are then weighed to the nearest milligram, ashed at 500°C, rewetted with distilled water to replace the water of hydration, oven dried, and weighed again. Biomass is reported as mg ash-free dry weight per cm^2.

Slides collected for taxonomic identification and enumeration are scraped into an appropriate volume of water along with a sufficient amount of preservative to limit microbial growth and/or algal decomposition. The resulting solution is mixed thoroughly, and an aliquot withdrawn for quantitative analysis using aninverted microscope at a magnification of 560X.

8.6.2.4 Methods of Analysis

The following data are tabulated:

1. Species identification.
2. Total taxa by sample and station.
3. Density (units/cm^2).
4. Percent relative abundance.
5. Biomass (mg/cm^2) per sample.
6. Diversity (d).
7. Maximum diversity ($\log_2$ number of species).
8. Equitability percent.

Diversity measurements will indicate, by the relative abundance of certain indicator species, the relative impact of oil shale development on the periphyton communities.

The following hypotheses will be tested in this analysis:

H_0: No significant change exists in periphyton communities over time.

H_0: No significant difference exists in periphyton communities at control stations vs. development stations from baseline data, recognizing the differences during baseline.

Statistical analyses will be a comparison of productivity (biomass) and species diversity during monitoring versus baseline conditions, and include analysis of variance, correlation analysis, as well as non-parametric tests. A significant difference is based on statistical analysis and professional judgment. If the null hypotheses are rejected at $\alpha = 0.10$ level, daily water samples will be analyzed, periphyton sampling may be intensified in an effort to pinpoint the degradation, and as previously noted a systems dependent (fish shocking) study may be initiated.

8.6.2.5 Results and Conclusions

A total of 106 taxa were identified from Hunter and

Stewart Stations in Piceance Creek, Colorado from the monthly samples taken between May and October 1978 (Tables A8.6.2-1 through A8.6.2-6. These taxa were comprised of 84 diatom taxa (Bacillariophyta), 12 green algae taxa (Chlorophyta), six blue-green algae taxa (Cyanophyta), one cryptomonad taxon (Cryptophyta), and three yellow-brown algae taxa (Chrysophyta). Table A8.6.2-7 lists the taxa observed and their months and locations of occurrence and dominance during the study. Species diversity and biomass data for the six month study are summarized in Tables A8.6.2-8 and A8.2.6-9.

Variations in periphyton density occurred during the study period with minima recorded in May and maxima recorded the following month, June. Extreme station density differences occurred in August when the total density at Stewart Station was nearly five times less than at Hunter Station and in October when the total density at Hunter Station was over five times less than at Stewart Station.

In comparing the periphyton communities observed throughout the six month study period, a seasonal variation is apparent. In May and June the periphyton of both stations was predominately Navicula and Nitzschia species. In July, August, and September, both stations were predominated by Achnanthes species with Cocconeis species becoming codominant in August and September. October was the only month where significant differences were observed in the periphyton constituents of the two stations. Stewart Station continued to be dominated by Achnanthes and Cocconeis species while at Hunter Station the importance of Achnanthes species was diminished and Navicula and Cocconeis species occurred as dominants in the periphyton.

Annual variations also seem to be occurring in Piceance Creek based on comparisons of 1978 sampling to spring and fall periphyton analyses in 1977. In May 1977 Navicula viridula var. avenacea dominated while in 1978 other Navicula species and Nitzschia species dominated along with Cocconeis placentula at Hunter Station. The October 1978 samples at Hunter Station were similar to those observed in 1977. Stewart Station, however, was quite dissimilar with Achnanthes and Cocconeis species dominating.

The known ecological requirements and tolerances were similar for the diatom species found to dominate at some time in the study. They attain best development in alkaline waters and are common in oligotrophic and mesothropic rivers of this region (Lowe 1974 and Patrick and Reimer 1966). The Nitzschia species that dominated in spring and summer, however, are generally more common in standing waters.

Species diversity values for the study are summarized in Table A8.6.2-8. Diversity values decreased steadily at both stations between May and July then increased again in August. In September and October at Stewart Station the diversity was extremely low. In October the differences between stations apparent from the dominant taxa was also visible when comparing diversity values with Hunter Station diversity being considerably higher.

Biomass data are summarized for the study in Table A8.6.2-9. At Stewart Station mean biomass steadily decreased from 0.52 mg/cm^2 in May to 0.05 mg/cm^2 in August, increased to 0.35 mg/cm^2 in September, then decreased again to 0.13 mg/cm^2 in October. At Hunter Station, biomass increased to a maximum in June (1.66 mg/cm^2) and steadily decreased to the minimum recorded in October (0.22 mg/cm^2). During the six month study, productivity as determined by the biomass was highest

at Hunter Station.

In addition to the 1977 and 1978 periphyton data discussed in previous pages periphyton data were collected in 1974, 1975, and 1976 from Piceance Creek, Colorado (C-b Shale Oil Venture et. al 1977).

In comparing the 1974-1976 periphyton data to the 1977-1978 data, difficulties arise because sampling sites for the two studies were changed and in 1974-1976 there were gaps in the data collected due to destroyed samplers. For these reasons, meaningful comparisons can only be made between data collected from Stewart and Hunter Stations for 1977-1978 and data collected from similar sites at Stewart and Hunter Stations for 1974-1976.

Station PC-3 with periphyton community analysis data for 1974, 1975, and 1976 (Table A8.6.2-10) and biomass productivity data for 1975 and 1976 (Table A8.6.2-12) is downstream from and has been compared to Stewart Station. Station PC-6 with periphyton community analysis data for 1974, 1975, and 1976 (Table A8.6.2-11) and biomass productivity data for 1975 and 1976 (Table A8.6.2-12) is downstream from and has been compared to Hunter Station.

The periphyton community analysis data for 1974-1976 is qualitative only. No information is available for comparison on periphyton abundance and dominance.

Since the occurrence of a taxa in a sample could indicate the chance presence of a single individual unsuited to the present environmental conditions rather than a growth response of an organism to favorable conditions, dominant taxa (present at abundances greater than 5% of the total abundance) are often used to describe an algal community. In the case of the 1974-1976 data where dominance was not indicated, taxa dominating in 1977 and 1978 have been compared to those occurring in 1974-1976.

In the vicinity of Stewart Station there appears to be considerable annual variation in the periphyton community.

In spring 1978, Navicula tripunctata var. schizonenoides, Navicula secreta var. apiculata, Nitzschia palea, Nitzschia spp., and other pennate diatoms were the dominant taxa while in 1977 Navicula viridula var. avenacea was the only taxa present as a dominant. In 1976, when spring collection data is available, Navicula viridula and Nitzschia palea were the only taxa recorded that corresponded to the 1977 and 1978 dominants.

In summer 1978, three Achnanthes species, two Cocconeis species and Navicula secreta var. apiculata were the dominant taxa. Two of these six taxa were recorded as having occurred in 1976, Achnanthes sp. and Cocconeis placentula, while in 1975 Cocconeis placentula was the only taxa of the 1978 dominants recorded as present.

In fall, major annual differences were apparent in the vicinity of Stewart Station. In 1978 Achnanthes minutissima and Cocconeis pediculus dominated the periphyton. Navicula secreta var. apiculata and Navicula viridula var. avenacea were the dominant taxa, in 1977. Of the taxa found in abundance in 1977 and 1978, Navicula viridula occurred in the fall periphyton collection

in 1975 and Cocconeis sp. and Navicula sp. occurred in 1974.

In the vicinity of Hunter Station some annual variation was apparent. In spring 1977, Navicula viridula var. avenacea dominated the periphyton community. In addition to this taxa, in 1978 Achnanthes minutissima, Navicula cryptocephala, N. secreta var. apiculata, N. viridula var. avenacea, N. tripunctata var. schizonemoides, Nitzschia palea, Nitzschia spp., and other pennate diatoms occurred as dominants. Of these 1977 and 1978 dominant taxa, Navicula cryptocephala and N. viridula were recorded from the periphyton in the spring of 1975 and 1976.

In summer during 1978, three Achnanthes species and two Cocconeis species dominated the periphyton collection. Of these taxa Cocconeis placentula was recorded occurring in 1975 and 1976. In addition, Achnanthes lanceolata occurred in 1976.

In fall 1977 Navicula viridula var. avenacea and N. secreta var. apiculata were the dominant taxa. In 1978 the dominant taxa were these same two Navicula taxa, Achnanthes lanceolata var. dubia, and two Cocconeis species. Of these dominant taxa of 1977 and 1978, two occurred in the fall samples of 1975, Navicula viridula and Cocconeis placentula. In 1974 Achnanthes sp., Cocconeis placentula, and Navicula sp. were the taxa occurring in common with the 1977 and 1978 dominants.

Differences in sampling techniques and levels of taxonomic expertise may be responsible for some of the variation observed between the periphyton communities of 1974-1976 and 1977-1978. Although annual differences have apparently occurred, the reasons for these differences are not immediately apparent. Combinations of a number of environmental factors such as light (turbidity), temperature, flow rate, nutrients, and pH all effect the periphyton community. Any or all of these factors may vary on an annual basis irrespective of any man-made perturbations.

Although variability in the periphyton communities is apparent annually, seasonally, and between stations, most of the taxa observed over the five year study in the vicinity of Stewart and Hunter Stations were diatoms with similar environmental requirements. According to Lowe (1974) most of the diatom taxa observed attain best development in alkaline waters (pH> 7) of relatively high inorganic nutrient concentrations. They are common in small or large streams of ponds. Most of the taxa recorded as abundant are considered to be cold water forms.

The seasonal fluctuation apparent in ash-free dry weight biomass productivity was highest in summer and fall when light and temperature were optimum for growth. Spate and drought occurrences are probably the most important factors governing the time and degree of high productivity in the summer and fall. In 1975 productivity was high in late summer and fall while in 1976 the high values occurred in spring and early summer with a low value in mid-summer (July). A July 1976 high flow rate of approximately 40 cfs could have scoured the periphytic algae from the glass slides and reduced

the recordable biomass productivity. Simarily in August 1978 productivity was low. Increased flow rate was probably the reason for this also. On an annual basis the range of productivity values recorded were generally comparable over the five year study.

Productivity at the different stations was also variable. In 1975, 1976, and 1977 biomass productivity tended to be higher at Stewart Station than at Hunter Station while in 1978 the reverse was true. Continued study will be required to determine if this trend will continue. Figure 8.6.2-1 graphically presents the productivity results for 1975-1978.

8.6.3 Water Quality

Surface water quality is now consolidated in Section 5.2

8.7 Terrestrial Studies

The terrestrial studies portion of the Environmental Baseline Program was designed to describe the predevelopment, biological environment within the study area (the dotted lines of the jacket map) and to provide baseline data to be used in monitoring changes in the biota as a result of oil shale development. Baseline parameters were selected for their usefulness in describing the existing environment on Tract C-b. Development monitoring parameters were judged to be useful because of their measurability or observability or relative low natural variability, and/or sensitivity to expected environmental perturbations. Sample locations during Development Monitoring are shown on the jacket map.

8.7.1 Vegetation Community Structure and Composition

8.7.1.1 Scope and Rationale

The vegetation community structure and composition studies are conducted to evaluate major changes in the makeup of the major plant communities on the Tract. Other vegetation monitoring programs provide a better means for statistically evaluating changes. The structure and composition studies are better used for evaluating general vegetational trends. These studies are centered on the six intensive study sites which are sampled on a three year rotational basis. Chained pinyon-juniper rangeland Plots were sampled in 1978, pinyon-juniper woodland Plots will be sampled in 1979 and sagebrush Plots will be sampled in 1980.

8.7.1.2 Objectives

The objective of the community structure and composition studies is to obtain long-term data from permanently located sampling quadrats so as to evaluate differences in numerous species. The productivity studies, discussed later, focus on monitoring a process; the structure and composition studies focus on the performance of species within the major vegetation types.

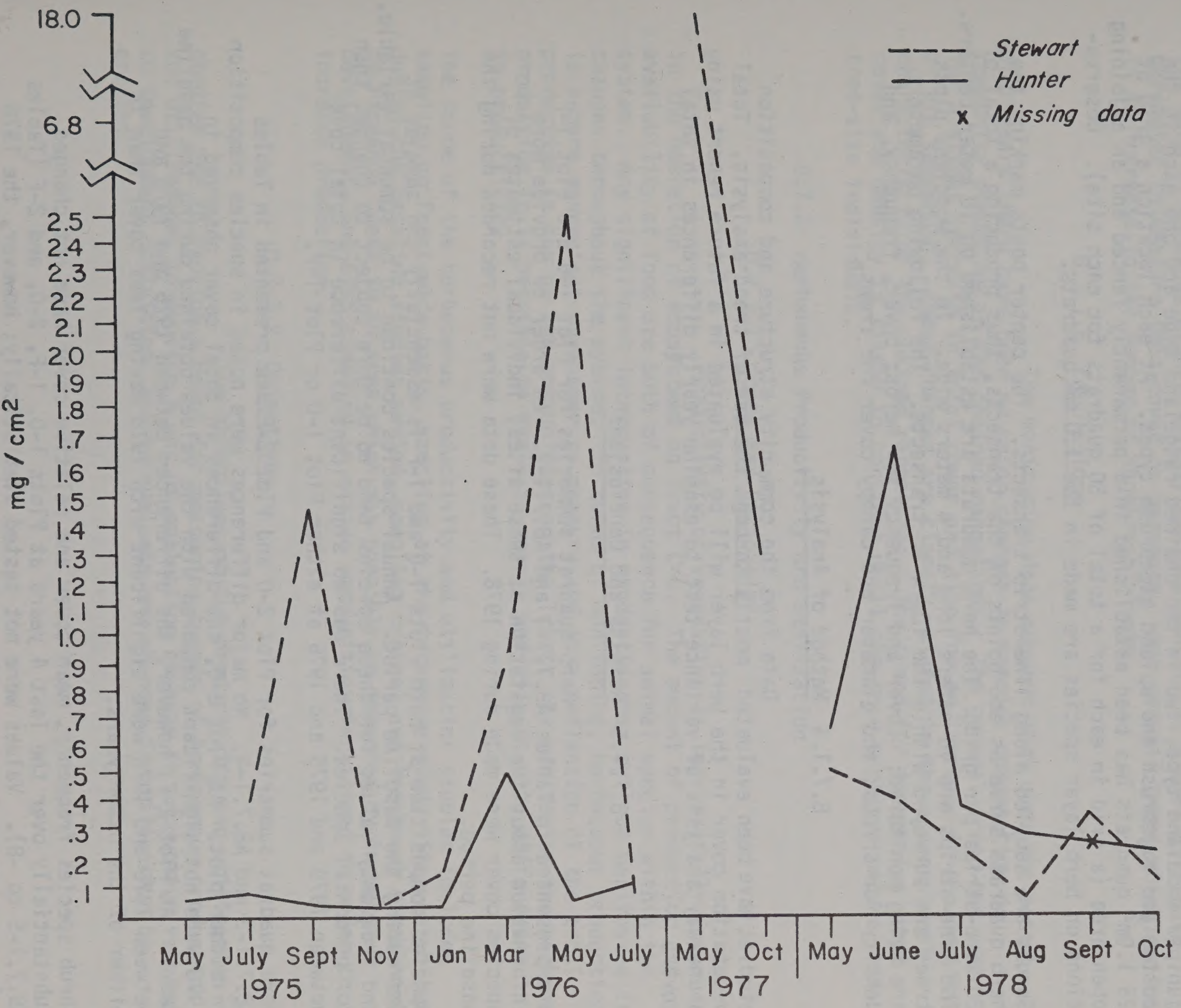

FIGURE 8.6.2-1 PERIPHYTON ASH-FREE DRY WEIGHT PRODUCTIVITY (mg/cm^2) FROM PICEANCE CREEK, COLORADO IN THE VICINITY OF STEWART AND HUNTER STATIONS, 1975-1978

8.7.1.3 Experimental Design

The community structure and composition studies are conducted at the six intensive study plots. Two are located in the pinyon-juniper woodland type, two in the chained rangeland type and one each in the bottomland sagebrush and upland sagebrush types. At each location a grid of 25 $1.0m^2$ quadrats has been established in a permanently fenced and an adjoining open area (a grid in each for a total of 50 quadrats for each site). Observations on herb layer species are made in the 1.0 m^2 quadrats.

Shrubs are sampled along line-strip transects. The center posts marking the herb quadrats serve as end points of the transects, thus producing a total of 20 line-strips per grid. The herb quadrats are established on 10 meter centers. The line-strips are 10 meters long and 4 meters wide. In the woodland plots, trees are surveyed within the 10m x 4m transects. The following parameters are being monitored: cover and frequency for herbs; cover, frequency, and density for shrubs; and diameter and canopy cover for trees.

8.7.1.4 Method of Analysis

Data from the community structure and composition studies have been evaluated mostly through the use of trend analysis. Total vegetation cover in the herb layer will be evaluated in a future report using a one-way analysis of variance test to examine yearly differences in total cover.

8.7.1.5 Results and Conclusions

Herb quadrat summaries for Plot 1-0 and Plot 1-F are presented in Tables A8.7.1-1 and A8.7.1-2. In order to provide more information about the vegetation at these sites, individual estimates of species cover were made during 1978. These data were not recorded during the baseline period.

Species composition at both Plots 1-0 and 1-F is essentially the same as it was during the baseline period. Annual species continue to be somewhat variable, and frequency values for these species tend to be more subject to changes than for perennial species. There was no significant difference in total cover between 1978 and 1975 and 1976 at either Plot 1-0 or Plot 1-F.

Herb quadrat summaries for Plot 2-0 and Plot 2-F are presented in Tables A8.7.1-3 and A8.7.1-4. No major differences were noted in species composition in either plot. At Plot 2-0, the differences in total cover observed in 1978 were not significant compared with the values obtained during the baseline years. At Plot 2-F, however, the differences between 1975 and 1978 and between 1976 and 1978 were significant with 1978 having less cover than in either of the other years.

Shrub species frequency, mean cover and relative cover have not changed substantially over the last 4 years at Plots 1-0, 1-F, 2-0, and 2-F (Tables A8.7.1-5 to -8). Values were not tested statistically; however, the 1978 values appear to be comparable to those obtained during the baseline period.

During 1978, Juniperus scopulorum was not separated from Juniperus osteosperma. The fact that J. scopolorum did not appear in the data was a result of misidentification. Density values for shrubs were also comparable to those obtained during the baseline period (Table A8.7.1-9). The variability in the data is somewhat higher, mainly because density is a more difficult parameter to measure than cover or presence. One general trend which can be seen is an increase in the number of sagebrush plants.

8.7.1.6 Conclusions

The monitoring data suggest that over the past four years there have been no major changes in species composition or community structure in the chained rangelands. The general trend has been for a slight increase in total cover and also for an increase in the density of big sagebrush. These changes are closely related to the successional characteristic of the chained rangelands. The trend for increasing shrub cover and density is likely to continue until the tree saplings mature into tree-size individuals.

8.7.2 Herbaceous Productivity and Utilization

8.7.2.1 Scope and Rationale

Productivity of vegetation is intrinsically important in the operation of ecosystems on Tract C-b. The amount of production and availability of food are both of consequence for animal species within the system. Any significant interruption in production may well be manifested in changes throughout the system. In terms of monitoring, herbaceous production is a more convenient parameter to measure and is a reflection of the total production in any of the communities on the Tract. By monitoring the herbaceous production it is possible to evaluate yearly and site-to-site differences in productivity.

The scope of the herbaceous productivity and utilization studies includes sampling on Tract-wide basis, sampling at the intensive study sites established during the baseline studies period, sampling control and treatment sites north of Piceance Creek in an area which may possibly be impacted by industrial development, and also sampling in native communities fertilized in order to increase production.

8.7.2.2 Objectives

The objectives of the productivity and utilization studies are to provide a means for measuring trends of herbaceous production and utilization, to provide a way of evaluating changes in production related to development activities, and to evaluate any changes in utilization by grazing.

8.7.2.3 Experimental Design

Herbaceous production and utilization are being studied on a Tract-wide basis through the use of randomly located exclosures. These exclosures (range cages) are small in size and prevent grazing by large herbivores on more than one square meter of ground. Ten exclosures are placed throughout the Tract in each of the four major plant communities (pinyon-juniper woodlands, chained pinyon-juniper rangelands, upland sagebrush shrublands, and bottomland sagebrush shrublands). The range cages are clipped in late July and all of the current years growth is fractionated on the basis of species for western wheatgrass (*Agropyron smithii*), cheatgrass (*Bromus tectorum*), and Indian ricegrass (*Oryzopsis hymenoides*); and on the basis of life form for other perennial grasses, other annual grasses, perennial forbs, annual forbs, and half-shrubs. At the same time the cages are clipped, a randomly located quadrat of the same size is clipped in an area close to the range cage in order to obtain the necessary data for evaluating utilization. The clipped samples are returned to the lab, oven dried to a constant weight, and then weighed to the nearest milligram.

Production studies at the intensive study sites are being conducted using a double sampling approach. Fifty one-square meter quadrats are randomly located in seasonally fenced plots at the intensive study sites. (Fences are put up at the beginning of the growing season and removed after the studies have been completed at the end of the season). The weight in grams for each of the current years growth fractions is estimated in each of the fifty quadrats. Ten of the quadrats are clipped in addition to being estimated. Once the samples have been dried and weighed, regression equations are developed for each of the species or species groups. All of the fresh estimates are then corrected to an oven dry weight on the basis of the derived equations. Total production estimates are derived from an equation rather than by summing individual fractions for each quadrat. Data from these studies are compared with information derived during baseline periods and are also used to compare vegetation types and study sites within any given year.

The areas north of Piceance Creek have been identified as possible sulfur dioxide accumulation areas. In order to evaluate potential air pollution effects, herbaceous production estimates are to be obtained in the affected area as well as in a comparable control area. In 1978 both the affected and control sites were sampled using ten randomly located range cages in each area. Open areas near each of the cages were also clipped in order to evaluate utilization at each site. Samples were obtained and handled in the same manner as that used for other range cage studies. These data will serve as the baseline for evaluating changes in the affected area.

The effects of fertilization in native vegetation types are also being monitored. Two different fertilizer treatments (ammonium nitrate and ammonium nitrate plus phosphorus) are being employed at two sites in the chained rangeland community type. One range cage is randomly located within each treatment at each site.

Control data are obtained from sites adjacent to the fertilizer application areas. Open areas near the range cages are clipped in order to evaluate utilization in the fertilizer areas. The data are collected and handled in the same manner as in other range cage studies.

8.7.2.4 Methods of Analyses

Analysis of the herbaceous production data is focused on four areas of comparison. These include the evaluation of:

1. Differences among vegetation types during a given growing season.
2. Differences between study sites of the same vegetation type during a given growing season.
3. Differences between years within a given vegetation type.
4. Differences between fenced and open areas within a vegetation type during a given growing season.

Total production is used as the parameter for comparison. Evaluation of differences is accomplished using a one-way analysis of variance (F-test) to test whether or not the means in question are the same.

8.7.2.5 Results and Discussion

Tract-wide Range Cage Studies. The Tract-wide range cage studies were used to obtain a more broadly based estimate of production than that derived from the intensive study plots. Each of the four major vegetation types is discussed separately.

Data from each of range cages sampled in the pinyon-juniper woodland type are presented in Table A8.7.2-1. Total production in the pinyon-juniper woodlands averaged 21.4 g/m^2 (191 lbs/ac) and only 9.8 g/m^2 (87 lbs/ac) in open areas near the cages (Table A8.7.2-2). In both cases most of the production was attributable to perennial grasses. Annual forbs and half-shrubs occurred only sporadically.

Oven dry weight data from the chained rangeland range cages and open areas are presented in Table A8.7.2-3. Total production averaged 63.5 g/m^2 (566 lbs/ac) for the range cages and 53.2 g/m^2 (474 lbs/ac) for the open areas. The greatest percentage of the production was attributable to Indian ricegrass, western wheatgrass and the other perennial grasses (Table A8.7.2-4)

Oven dry weight data for range cages and open areas in the upland sagebrush shrubland type are presented in Table A8.7.2-5 . Total production averaged 68.0 g/m^2 (606 lbs/ac) in the range cages and 47.2 g/m^2 (420 lbs/ac) in the open areas. Major producing species included western wheatgrass and other perennial grasses (Table A8.7.2-6). Forbs accounted for less than 10 percent of the total production. Half-shrubs were encountered occasionally; however when they occurred in the sample, they contributed substantially to the total production.

Data from the range cages and open areas in the bottomland sagebrush shrubland type are presented in Table A8.7.2-7. Total production averaged 32.9 g/m^2 (293 lbs/ac) in the range cages and 16.6 g/m^2 (148 lbs/ac) in the open areas. The dominant species was cheatgrass which accounted for 45 percent of the production in the range cages and 34 percent of the production in the open areas (Table A8.7.2-8).

Intensive Study Plots - 1977. Field data and oven dry weights from May, June and July, 1977 for the six intensive study plots were presented in the 1977 Tract C-b interim monitoring data report. The results presented in this section are summaries based on regression equations derived from the May, June and July data (Tables A8.7.2-9 to -11).

1977 was a very dry year on the Tract, and total production estimates were substantially lower than those reported for previous years. Not only were the production estimates lower, but the pattern of seasonal development was also different from previous years. In some cases the maximum standing crop was attained in May, whereas in more normal precipitation years maximum standing crop was not reached until July.

Production data for chained rangeland Plots 1-0 and 1-F for May, June and July are presented in Tables A8.7.2-12 to -14. Maximum standing crop in the fenced plot was 11.1 g/m^2 (99 lbs/ac) and was measured in July. In the open plot maximum standing crop was 8.8 g/m^2 (78 lbs/ac) and was also measured in July. Most of the production in both the open and fenced plots was attributable to perennial grasses. In chained rangeland Plots 2-0 and 2-F (Tables A8.7-2-15 to -17) the maximum standing crop was 12.5 g/m^2 (111 lbs/ac) in May for the fenced plot and 9.5 g/m^2 (85 lbs/ac) in May for the open plot.

Maximum standing crop in the upland sagebrush shrubland type (Plots 3-0 and 3-F) was reached in May (Tables A8.7.2-18 to -20). In Plot 3-F the maximum standing crop was 18.2 g/m^2 (162 lbs/ac) and in Plot 3-0 was 12.2 g/m^2 (109 lbs/ac). Most of the standing crop was attributable to western wheatgrass and other perennial grasses.

Production data for the bottomland sagebrush Plots 4-0 and 4-F (May, June and July) are presented in Tables A8.7.2-21 to -23. Maximum standing crop for both the open and fenced plots was measured in July. In the fenced plot total production was only 4.5 g/m^2 (40 lbs/ac) and in the open plot was only 4.6 g/m^2 (41 lbs/ac). Cheatgrass, which had been encountered as a major species in previous years, was nearly absent from the sample. Cheatgrass is an annual species and under the very dry conditions of the 1977 growing season, grew hardly at all.

Production data for pinyon-juniper woodland Plots 5-0 and 5-F are presented in Tables A8.7.2-24 to -26. Maximum standing crop in Plot 5-F averaged 6.2 g/m^2 (55 lbs/ac) and occurred in May. In Plot 5-0 the maximum standing crop was only 5.1 g/m^2 (45 lbs/ac) also recorded in May. Most of the production was provided by perennial grasses. Production at the other pinyon-juniper study site (Plots 6-0 and 6-F) was somewhat higher than at Plot 5 (Tables A8.7.2-27 to -29). Maximum standing crop averaged 6.4 g/m^2 (57 lbs/ac)

in Plot 6-F in July and 9.9 g/m2 (88 lbs/ac) in Plot 6-0 in May. As in Plot 5, most of production was provided by perennial grass species.

Intensive Study Plots - 1978. During 1978, clipping studies were conducted only in Plots 1-F, 2-F, 5-F and 6-F, and sites were clipped only once during the growing season (late July). At this date all of the material produced during the growing season was clipped. Fresh weight estimates for each of the plots are presented in Tables A8.7.2-30 to 33, and the oven dry weights for each of the clipped quadrats are presented in Tables A8.7.2-34 and 35. The dry weight estimates and corresponding oven dry weights were used to develop the regression equations in Table A8.7.2-36.

Based on data derived from the regression equations the production at Plot 1-F averaged 29.5 g/m^2 (263 lbs/ac) (Table A8.7.2-37). The major species were Indian ricegrass and other perennial grasses. At Plot 2-F herb production averaged 24.4 g/m^2 (217 lbs/ac) (Table A8.7.2-37). Major species at this site included western wheatgrass, Indian ricegrass and other perennial grasses. Cheatgrass was also quite abundant and averaged 4.0 g/m^2 (36 lbs/ac).

Production at pinyon-juniper woodland Plot 5-F was lower than that for the chained rangeland sites and averaged only 19.2 g/m^2 (171 lbs/ac) (Table A8.7.2-38). Major species included Indian ricegrass and other perennial grasses. Plot 6-F was more than twice as productive and averaged 50.3 g/m^2 (448 lbs/ac) (Table A8.7.2-38). This same relationship between plots 5-F and 6-F was observed during the baseline period and to a lesser extent during the suspension monitoring period.

Studies Conducted North of Piceance Creek. Oven dry weight data for range cages and open areas in the anticipated affected area and control area are presented in Tables A8.7.2-39 and 40, respectively. On the affected area site, production averaged 19.7 g/m^2 (175 lbs/ac) in the range cages and 9.8 g/m^2 (87 lbs/ac) in the open areas. In both instances most of the production was attributable to Indian ricegrass and other perennial grasses (Table A8.7.2-41).

In the control area, production averaged 17.8 g/m^2 (150 lbs/ac) in the range cages and 6.6 g/m^2 (59 lbs/ac) in the open areas (Table A8.7.2-42). Indian ricegrass and other perennial grasses were the most productive species. The pinyon-juniper woodlands on these sites north of Piceance Creek occur on dry, south-facing slopes. In terms of slope and aspect, they are quite similar to intensive study Plot 5 on the Tract. It is interesting to note that the production on the control and affected area sites was comparable to that measured at Plot 5-F.

Fertilization Studies. Fertilized areas are shown on Figure 8.7.2-1. Oven dry weights from range cages and open areas in the different fertilizer treatment locations are presented in Table 8.7.2-1. These data were grouped in various ways in order to evaluate the effects of fertilization, location effects, and grazing effects in the fertilizer plots.

N-P AMMONIUM NITRATE & PHOSPHOROUS FERTILIZER APPLICATION
N AMMONIUM NITRATE

FERTILIZATION MAP

FIGURE 8.7.2-1

Table 8.7.2-1 . Production values (oven dry weights in grams/m^2) from range cages and open plots for fertilized and non-fertilized areas on the Ridge above Cottonwood Gulch and Scandard Ridge. 1978.

	Ridge Above Cottonwood Gulch		Scandard Ridge	
	Fenced Plot	Open Plot	Fenced Plot	Open Plot
Fertilized with Ammonium Nitrate and Phosphorus				
Agropyron smithii	18.076	15.575		
Bromus tectorum			45.251	46.747
Oryzopsis hymenoides	28.119	30.727	9.189	33.980
Other perennial grasses	26.872	6.874	0.206	1.179
Perennial forbs	8.092	5.039	0.005	4.639
Annual forbs			0.157	0.088
Total biomass	81.159	58.215	54.808	86.633
Fertilized with Ammonium Nitrate				
Agropyron smithii	10.152	15.163	0.205	
Bromus tectorum		6.055		
Oryzopsis hymenoides		0.923	0.236	
Other perennial grasses	73.040		25.243	27.770
Perennial forbs			0.801	1.480
Annual forbs		6.691		0.675
Total biomass	83.192	28.832	26.485	29.925
Not Fertilized				
Agropyron smithii	11.314	5.466	7.854	
Bromus tectorum	0.158	0.670	0.092	0.707
Oryzopsis hymenoides				
Other perennial grasses	51.343	0.840	17.839	28.442
Perennial forbs	6.284	5.299	4.028	
Annual forbs	0.129	0.154		0.256
Half shrubs		0.128		
Total biomass	69.228	12.557	29.813	29.405

There was no significant difference between the production in the fertilized and non-fertilized areas (tested with an F-test at $\alpha = 0.10$). The mean production on the fertilized area was greater (56.2 g/m^2) compared with non-fertilized (35.2 g/m^2), however the difference was not significant. Also, the differences in the type of fertilizer used were not significant (42.1 g/m^2 with ammonium nitrate alone and 70.2 g/m^2 with ammonium nitrate plus phosphorus). There was no significant difference between the plots on Scandard Ridge and those on the ridge above Cottonwood Gulch. Considering all the range cages used in the fertilization study there were no significant differences between the range cage and the open quadrats, suggesting limited utilization of the two sites as whole. However, the difference between the open quadrats and range cages on the ridge above Cottonwood Gulch was significant.

At this time the results from the fertilization studies are inconclusive. Apparently the fertilization is causing an increase in production, but because of the variability of the data and the limited sample sizes these differences are statistically not significant.

Evaluation of Production Differences.

Differences Among Vegetation Types. Because of the increased sample size associated with the change in methods used for estimated production, it has been possible to more clearly evaluate differences among the four major types (Table 8.7.2-2). In 1977 the chained rangelands were significantly more productive than both the pinyon-juniper woodlands and bottomland sagebrush shrublands. The upland sagebrush shrublands were significantly more productive than any of the other vegetation types. The pinyon-juniper woodlands were significantly more productive than the bottomland sagebrush shrublands. In 1978 the chained rangelands and upland sagebrush shrublands were significantly more productive than the pinyon-juniper woodlands and bottomland sagebrush shrublands. The differences between the pinyon-juniper woodlands and bottomland sagebrush shrublands, and between the chained rangelands and upland sagebrush shrublands were not significant in 1978. The pattern of differences observed in both 1977 and 1978 is consistent with the data obtained during the baseline period. In terms of the herbaceous production the upland sagebrush shrublands tend to be the most productive, followed by the chained rangelands, pinyon- juniper woodlands and bottomland sagebrush shrublands.

Differences Related to Development Effects. In 1977 there were no significant differences between Plots 1-F and 2-F or 5-F and 6-F (Table 8.7.2-3). Production was very low at all of the intensive study sites. In the pinyon-juniper woodland plots, the production was greater at Plot 6-F than at Plot 5, but the difference was not significant. Throughout the baseline period Plot 6 was more productive than Plot 5. This trend was also apparent in 1978 when the difference between Plots 5 and 6 was significant. It is highly doubtful that this difference is related to any development activities. It is most likely related to inherent site differences between Plots 5 and 6. Plot 5 occurs on dry east-facing slope and Plot 6 occurs on a ridgetop where soil and moisture conditions are apparently more favorable.

Table 8.7.2-2 . One-way analysis of variance results for comparisons of production among vegetation types, 1977 and 1978. Underlined plots are those with the significantly greater production.

	Calculated F	ν_1	ν_2	Critical Region α = 0.10 F>	Significance*
DIFFERENCES AMONG VEGETATION TYPES-1977					
Chained Rangeland vs. Pinyon-Juniper					
1-F July vs. 5-F May	20.774	1	98	2.764	SIG
1-F July vs. 6-F July	18.497	1	98	2.764	SIG
2-F May vs. 5-F May	22.619	1	98	2.764	SIG
2-F May vs. 6-F July	20.776	1	98	2.764	SIG
Upland Sagebrush vs. Pinyon Juniper					
3-F May vs. 5-F May	223.214	1	98	2.764	SIG
3-F May vs. 6-F July	203.364	1	98	2.764	SIG
Bottomland Sagebrush vs. Pinyon-Juniper					
4-F July vs. 5-F May	4.044	1	98	2.764	SIG
4-F July vs. 6-F July	4.729	1	98	2.764	SIG
Upland Sagebrush vs. Chained Rangeland					
3-F May vs. 1-F July	40.586	1	98	2.764	SIG
3-F May vs. 2-F May	17.279	1	98	2.764	SIG
Bottomland Sagebrush vs. Chained Rangeland					
4-F July vs. 1-F July	31.709	1	98	2.764	SIG
4-F July vs. 2-F May	32.487	1	98	2.764	SIG
Upland Sagebrush vs. Bottomland Sagebrush					
3-F May vs. 4-F July	212.209	1	98	2.764	SIG
DIFFERENCES AMONG VEGETATION TYPES-1978 (Based on Range Cages)					
Pinyon-Juniper vs. Chained Rangeland	7.464	1	16	3.05	SIG
Pinyon-Juniper vs. Upland Sagebrush	12.914	1	17	3.03	SIG
Pinyon-Juniper vs. Bottomland Sagebrush	1.622	1	17	3.03	NS
Chained Rangeland vs. Upland Sagebrush	0.067	1	17	3.03	NS
Chained Rangeland vs. Bottomland Sagebrush	4.598	1	17	3.03	SIG
Upland Sagebrush vs. Bottomland Sagebrush	8.154	1	18	3.01	SIG

* NS = Not significant
SIG = Significant

Table 8.7.2-3

One-way analysis results for comparisons evaluating development effects at Plots 1,2,5, and 6 and potential pollution effects north of Piceance Creek. Underlined plots are those with the significantly greater production.

	Calculated F	ν_1	ν_2	Critical Region $\alpha = 0.10$ F>	Significance*
DEVELOPMENT EFFECTS - 1977					
1-F July vs. 2-F May	0.883	1	98	2.764	NS
5-F May vs. 6-F July	0.066	1	98	2.764	NS
DEVELOPMENT EFFECTS - 1978					
1-F vs. 2-F	2.725	1	98	2.764	NS
5-F vs. 6-F	59.302	1	98	2.764	SIG
POTENTIAL POLLUTION EFFECTS - 1978					
Pinyon-Juniper north of Piceance Creek, Treatment vs. Control Fenced	0.124	1	18	3.01	NS
Pinyon-Juniper north of Piceance Creek, Treatment vs. Control Open	1.652	1	18	3.01	NS

* NS = Not Significant
SIG = Significant

ν_1 is the degree of freedom for numerator
ν_2 is the degree of freedom for denominator

There was no significant difference between the affected area site and control site in the potential pollution study area north of Piceance Creek (Table 8.7.2-3). This is to be expected inasmuch as no emissions yet exist. Tests were conducted on both the data from the range cages and data from the open areas. Neither were significantly different. It is fortunate that the control and affected area sites are so similar. Future comparisons will be more easy to conduct than if the sites were drastically different.

Differences Among Years. In the pinyon-juniper woodlands 1975 and 1976 were both significantly more productive than 1977 (Table 8.7.2-4), and 1978 was significantly more productive than 1975, 1976, and 1977 in all cases except for Plot 5 where the difference between 1975 and 1978 was not significant. The most dramatic differences occurred between the years 1977 and 1978. 1977 was a very dry year and 1978 was one of the most moist.

In the chained rangelands the differences among years were similar to those observed for the pinyon-juniper woodlands. 1975 and 1976 were significantly more productive than 1977, and 1978 was significantly more productive than 1976 and 1977, except at Plot 1 where the difference between 1976 and 1978 was not significant. Differences between 1975 and 1978 were not consistent. In some Plots, 1975 was significantly more productive and other cases 1978 was more productive.

In the upland sagebrush shrublands the same pattern was observed. 1975 and 1976 were significantly more productive than 1977, and 1978 was significantly more productive than 1976 and 1977. The difference between 1975 and 1978 was not significant.

For the bottomland sagebrush shrublands the yearly differences were the same as those observed in the upland sagebrush shrublands (Table 8.7.2-4).

The significant differences between years emphasize the importance of yearly changes in precipitation, and point to the responsiveness of the vegetation. The species are adapted to withstand dry years and grow only to a limited extent. In moist years these same species have the ability to produce more than five times the amount produced during a dry year.

Evaluation of Utilization. During the baseline period utilization was observed to be occurring early in the growing season and then again late in the season. For the middle part of the summer the livestock were grazing at elevations higher than the Tract. A similar pattern was observed during 1977 (Table 8.7.2-5). In May the differences between open and fenced plots were either not significant or the fenced plots were greater, except for Plot 6. In June half of the fenced plots were more productive and half were either more productive in the open plots or were not significantly different. By July the only significant difference was measured at Plot 1 where the fenced plot was more productive, suggesting that by the time of clipping in late July the open areas and fenced areas had mostly equalized in terms of herbaceous production.

Table 8.7.2-4 . One-way analysis of variance results for comparisons of production among years 1975-1978. Underlined years in each pair is the year with the significantly greater production.

	Calculated F	ν_1	ν_2	Critical Region $\alpha = 0.10$ F>	Significance*
DIFFERENCES AMONG YEARS					
Pinyon-Juniper Woodland					
1975 Plot 5 Combined Data vs. 1977 Plot 5 May	53.214	1	68	2.785	SIG
1976 Plot 5 Combined Data vs. 1977 Plot 5 May	7.121	1	77	2.777	SIG
1977 Plot 5 May vs. 1978 Plot 5	29.365	1	98	2.764	SIG
1975 Plot 6 Combined Data vs. 1977 Plot 6 July	31.082	1	68	2.785	SIG
1976 Plot 6 Combined Data vs. 1977 Plot 6 July	28.721	1	77	2.777	SIG
1977 Plot 6 July Data vs. 1978 Plot 6 Data	171.716	1	98	2.764	SIG
1975 Plot 5 Combined Data vs. 1978 Plot 5	1.153	1	68	2.785	NS
1976 Plot 5 Combined Data vs. 1978 Plot 5	6.353	1	77	2.777	SIG
1975 Plot 6 Combined Data vs. 1978 Plot 6	5.016	1	68	2.785	SIG
1976 Plot 6 Combined Data vs. 1978 Plot 6	26.604	1	77	2.777	SIG
Chained Rangeland					
1975 Plot 1 Combined Data vs. 1977 Plot 1 July	82.676	1	67	2.765	SIG
1976 Plot 1 Combined Data vs. 1977 Plot 1 July	10.635	1	77	2.777	SIG
1977 Plot 1 July Data vs. 1978 Plot 1	46.198	1	98	2.764	SIG
1975 Plot 2 Combined Data vs. 1977 Plot 2 May	13.951	1	68	2.785	SIG
1976 Plot 2 Combined Data vs. 1977 Plot 2 May	6.786	1	77	2.777	SIG
1977 Plot 2 May Data vs. 1978 Plot 2 Data	32.280	1	98	2.764	SIG
1975 Plot 1 Combined Data vs. 1978 Plot 1	12.088	1	67	2.785	SIG
1976 Plot 1 Combined Data vs. 1978 Plot 1	1.659	1	77	2.777	NS
1975 Plot 2 Combined Data vs. 1978 Plot 2	7.397	1	68	2.785	SIG
1976 Plot 2 Combined Data vs. 1978 Plot 2	0.001	1	77	2.777	NS

Table 8.7.2-4 . (Continued)

	Calculated F	ν_1	ν_2	Critical Region α = 0.10 F>	Significance*
Upland Sagebrush					
1975 Plot 3 Combined Data vs. 1977 Plot 3 May	101.372	1	68	2.785	SIG
1976 Plot 3 Combined Data vs. 1977 Plot 3 May	8.662	1	77	2.777	SIG
1977 Plot 3 May Data vs. 1978 Range Cages	106.954	1	58	2.795	SIG
1975 Plot 3 Combined Data vs. 1978 Range Cages	0.161	1	28	2.890	NS
1976 Plot 3 Combined Data vs. 1978 Range Cages	27.369	1	37	2.852	SIG
Bottomland Sagebrush					
1975 Combined Data Plot 4 vs. 1977 Plot 4 July	35.350	1	68	2.785	SIG
1976 Combined Data Plot 4 vs. 1977 Plot 4 July	17.940	1	77	2.777	SIG
1977 Plot 4 July vs. 1978 Range Cages	85.918	1	58	2.795	SIG
1975 Plot 4 Combined Data vs. 1978 Range Cages	0.254	1	28	2.890	NS
1976 Plot 4 Combined Data vs. 1978 Range Cages	7.332	1	37	2.852	SIG

* NS = Not Significant
SIG = Significant

γ_1 = degrees of freedom for numerator
γ_2 = degrees of freedom for denominator

Table 8.7.2-5 . One-way analysis of variance results for comparison of production in open and fenced plots, 1977 and 1978. Underlined plots are those with the significantly greater production.

	Calculated F	ν_1	ν_2	Critical Region $\alpha = 0.10$ F>	Significance*
DIFFERENCES IN UTILIZATION					
May 1977					
1-0 vs. 1-F	0.669	1	98	2.764	NS
2-0 vs. 2-F	4.024	1	98	2.764	SIG
3-0 vs. 3-F	69.473	1	98	2.764	SIG
4-0 vs. 4-F	0.470	1	98	2.764	NS
5-0 vs. 5-F	1.018	1	98	2.764	NS
6-0 vs. 6-F	22.204	1	98	2.764	SIG
June 1977					
1-0 vs. 1-F	3.657	1	98	2.764	SIG
2-0 vs. 2-F	5.326	1	98	2.764	SIG
3-0 vs. 3-F	5.851	1	98	2.764	SIG
4-0 vs. 4-F	0.210	1	98	2.764	NS
5-0 vs. 5-F	10.671	1	98	2.764	SIG
6-0 vs. 6-F	15.438	1	98	2.764	SIG
July 1977					
1-0 vs. 1-F	3.555	1	98	2.764	SIG
2-0 vs. 2-F	0.237	1	98	2.764	NS
3-0 vs. 3-F	0.503	1	98	2.764	NS
4-0 vs. 4-F	0.012	1	98	2.764	NS
5-0 vs. 5-F	0.016	1	98	2.764	NS
6-0 vs. 6-F	1.763	1	98	2.764	NS
1978 - Based on Range Cage Data					
Pinyon-Juniper Fenced vs. Pinyon-Juniper Open	2.591	1	16	3.05	NS
Chained Rangeland Fenced vs. Chained Rangeland Open	0.414	1	16	3.05	NS
Upland Sagebrush Fenced vs. Upland Sagebrush Open	2.413	1	18	3.01	NS
Bottomland Sagebrush Fenced vs. Bottomland Sagebrush Open	5.203	1	18	3.01	SIG
Pinyon-Juniper north of Piceance Creek, Treatment Site Open vs. Fenced	3.415	1	18	3.01	SIG
Pinyon-Juniper north of Piceance Creek, Control Site Open vs. Fenced	14.710	1	18	3.01	SIG

* NS = Not Significant, SIG = Significant

γ_1 = degrees of freedom for numerator ; γ_2 = degrees of freedom for denominator

In 1978 the only significant differences noted between range cage data and data from open areas were in the bottomland sagebrush shrubland type and in the control and affected area sites north of Piceance Creek. Differences in the pinyon-juniper woodlands on the Tract were not significant.

8.7.2.6 Conclusions

Several conclusions can be reached from the preliminary monitoring data.

1. The production patterns within vegetation types observed during monitoring period are the same as those observed during the baseline period.

2. Utilization continues to be seasonal and by mid-growing season is nearly non-detectable because of livestock use patterns.

3. Observed differences between intensive study Plots 1-F and 2-F, and 5-F and 6-F appear to be more related to site differences than to any development related activities.

4. Herbaceous production is closely related to precipitation. Significant differences between years are related to differences and fluctuating patterns of precipitation in this semi-arid region.

5. Fertilization of upland chained areas appears to result in an increase in herbaceous production. Because of a limited sample size and high data variability the differences between fertilized areas and control areas were not significant.

8.7.3 Shrub Production and Utilization

8.7.3.1 Scope and Rationale

Shrub production and utilization is measured each year to determine growth and utilization.

8.7.3.2 Objective

The main objectives for measuring shrub production and utilization were to correlate browse available and consumed by herbivores. over time and between stations.

8.7.3.3 Experimental Design

Production and utilization of bitterbrush were estimated along twelve transects on Tract during 1977-78 period. These transects were the same as those used for deer pellet-group studies and, consequently, transect notations were the same for both studies. Browse studies were also conducted on Big Jimmy ridge west of the tract, and although the same transects were again used for both pellet count and

browse studies, browse evaluation methods differ on Big Jimmy ridge. On tract, the lengths of new shoots in fall and spring were measured to provide production and utilization estimates. On Big Jimmy ridge, utilization was found to be so severe that current shoot growth and the consumption of this growth by deer could not be evaluated by shoot measurements. In many instances, shrubs were browsed back into the growth of the previous year. The information obtained for Big Jimmy ridge, therefore, concerns shrub density, reproduction, and vigor evaluations rather than production and utilization. Also, on Big Jimmy mountain mahogany as well as bitterbrush was sampled. Utilization of sagebrush was measured on all 27 deer pellet-group transects. Ocular estimates were made using pace transects and recording age and degree of hedging for each plant. An angle gauge was used to estimate sagebrush density on each transect.

8.7.3.4 Method of Analysis

Analysis performed included 1) correlation with past deer data, and 2) professional judgment.

8.7.3.5 Results and Discussions

Production and utilization estimates of bitterbrush and mountain mahogany for this past year differed markedly from 1976-77 estimates in that production was lower and utilization was much higher. Yearly patterns of mule deer habitat use as revealed by these data are not as similar as patterns revealed by pellet-group data. The 1977 production estimates for the twelve transects on tract (Tables A8.7.3-1 to -4) vary considerably from one location to another. The percent utilization estimates, in contrast, are comparatively uniform. For most transects, utilization was near the 90 percent level. This represents severe utilization, which appears to have been due mainly to a large deer herd and to low shrub production the previous year.

Trends in shrub production and utilization are shown on Figure 8.7.3-1. The low productivity and the high utilization which occurred during the 1977-78 period are clearly evident. A correlation coefficient was calculated to determine the intensity of association between the utilization estimates for the 1976-77 and 1977-78 periods. A low correlation was found to exist between the values obtained for the two years at the same transect locations ($r=0.4$; which is significant at the 80 percent level).

Only production data are available for the 1977-78 period (Table A8.7.3-5) since spring estimates of utilization have not yet been obtained. Bitterbrush and mountain mahogany evaluations for Big Jimmy ridge (Tables A8.7.3-6 and -7) represent the first year of browse data for this locality. As previously described, production and utilization estimates were not made because of severe utilization coupled with meager shrub production. A visual examination of production this past spring, however, indicates that shoot measurements will probably be feasible next year.

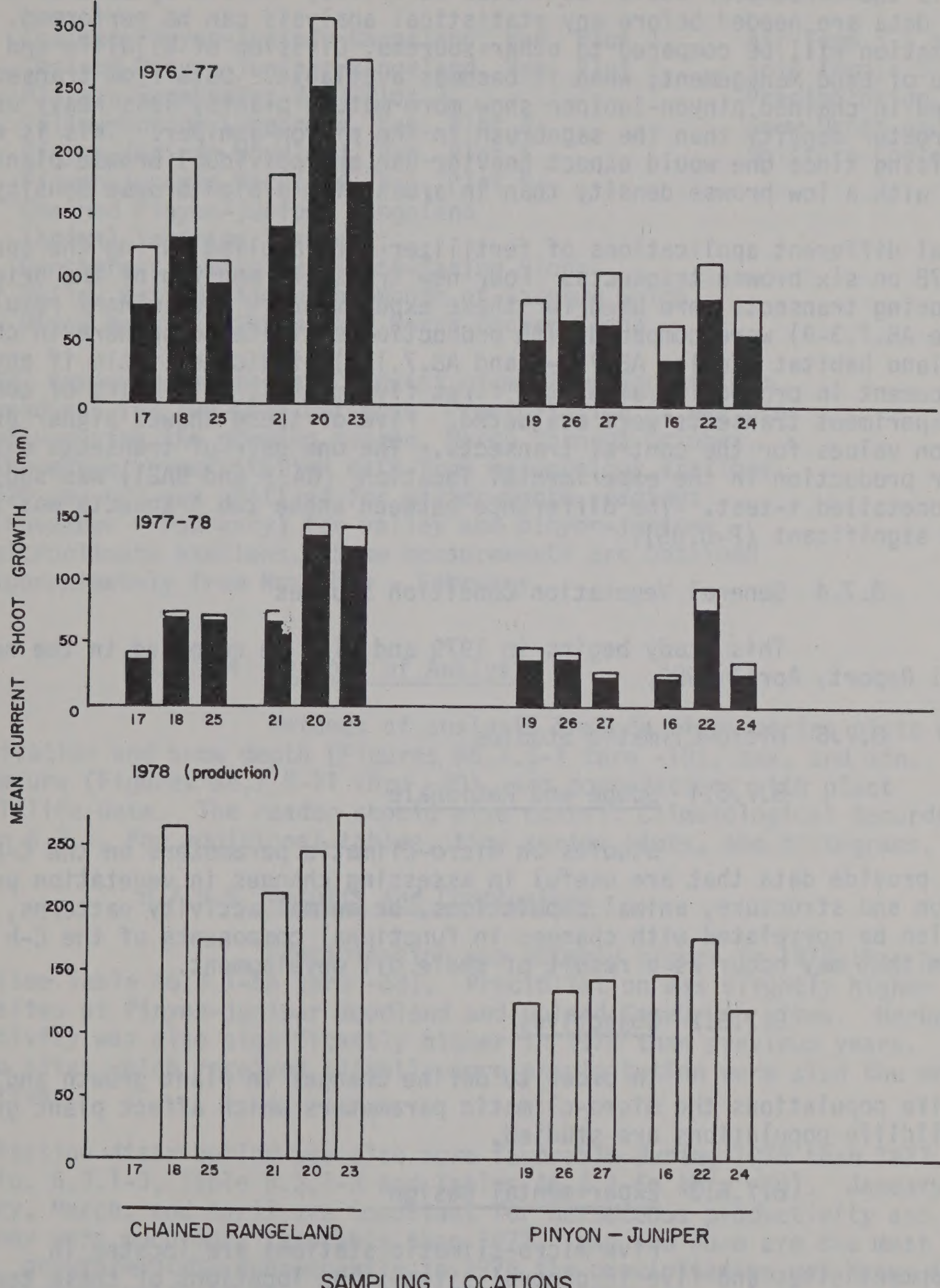

Fig. 8.7.3-1 Trends in production and utilization of bitterbush. Shaded areas and figures represent the percent of current shoot growth consumed by deer. Transect numbers are indicated below bars.

The 1978 sagebrush ocular estimate data are presented in Table A8.7.3-8. This is the first year ocular estimates were used, therefore, several years data are needed before any statistical analysis can be performed. Information will be compared to other sources, Division of Wildlife and Bureau of Land Management, when it becomes available. Data from transects located in chained pinyon-juniper show more mature plants, less heavy use, and greater density than the sagebrush in the pinyon-juniper. This is not surprising since one would expect heavier use on individual browse plants in areas with a low browse density than in areas with a high browse density.

Several different applications of fertilizer were applied during the spring of 1978 on six browse transects. Four new transects and two of the original monitoring transects were used for these experiments. Preliminary results (Table A8.7.3-9) were compared with production estimates elsewhere in chained rangeland habitat (Tables A8.7.3-1 and A8.7.1-3), indicate little if any enhancement in production after the first five months. Six pairs of control and experiment transects were evaluated. Five of these showed higher production values for the control transects. The one pair of transects with higher production in the experimental location (BA31 and BA21) was subjected to a onetailed t-test. The difference between these two transects was found to be significant ($P<0.05$).

8.7.4 General Vegetation Condition Studies

This study begins in 1979 and will be reported in the next Annual Report, April 1980.

8.7.5 Micro-Climatic Studies

8.7.5.1 <u>Scope and Rationale</u>

Studies on micro-climatic parameters on the C-b Tract provide data that are useful in assessing changes in vegetation production and structure, animal populations, or animal activity patterns, and may also be correlated with changes in functional components of the C-b ecosystem that may occur as a result of shale oil development.

8.7.5.2 <u>Objectives</u>

In order to define changes in plant growth and wildlife populations the micro-climatic parameters which affect plant growth and wildlife populations are studied.

8.7.5.3 <u>Experimental Design</u>

Five micro-climatic stations are located in development sites and five in control sites. The locations of these ten sites (see Sta BC01-09, 13 on the jacket map) are the same as baseline locations. Therefore, data from March 1975 through the present can be compared. Each station is monitored twice monthly for the following parameters:

Mc Station Locations		Parameters
BC01	Chained Pinyon-juniper Rangeland, Veg. Plot 1	Air Temp.: 1 m
BC02	Chained Pinyon-juniper Rangeland, Veg. Plot 2	Soil Temp.: Surface
BC03	Plateau Sagebrush, Veg. Plot 3	Precipitation
BC04	Valley Bottom Sagebrush, Veg. Plot 4	Snow Depth and
BC05	Pinyon-juniper Woodland, Veg. Plot 5	Moisture Content
BC06	Pinyon-juniper Woodland, Veg. Plot 6	
BC07	Chained Pinyon-juniper Rangeland (Animal Trapping Transect)	
BC08	Bunchgrass Community, South-facing Slope	
BC09	Valley Bottom Sagebrush, Mouth of Sorghum Gulch	
BC011	Mixed Mountain Shrubland, North-facing Slope	

All temperature readings consist of maximum and minimum readings for two-week periods. Precipitation is measured only during the growing season, March through October. Therefore, precipitation data from meteorology stations 020 and 023 are utilized for winter-month readings (November - February) for valley and pinyon-juniper microclimate stations. Snow measurements are obtained approximately from November - February.

8.7.5.4 Methods of Analysis

Methods of analysis include times series plots of precipitation and snow depth (Figures B8.7.5-1 thru -10), max. and min. temperature (Figures B8.7.5-11 thru -20), and correlations with plant and wildlife data. The reader should also consult Climatological Records, Section 6.3.1, for additional tables, time series plots, and histograms.

8.7.5.5 Results and Conclusions

Precipitation was notably higher in 1978 than previous years (See Table A6.3.1-6a thru -6d). Precipitation was slightly higher than other sites at Pinyon-juniper Woodland and Upland Sagebrush sites. Herbaceous productivity was also significantly higher in 1978 than previous years. Also, the two sites which received slightly more precipitation were also the most productive.

Precipitation distribution was also more favorable during 1978 than 1977. (See Fig. 6.3.1-3, Table 6.3.1-3 and Tables A6.3.1-6a thru -6d). January, February, March, and April are important for herbaceous productivity and in 1978 they were much more favorable than 1977. May and June are the most active growth periods; consequently in 1978 the precipitation was heavy and the herbaceous productivity was also high. In 1977, the only heavy storm was in July when vegetative growth was nil due to the dry conditions.

Temperature dropped to near 0° C over the growing season, but did not seem to be a limiting factor as it was in 1976 when a killing frost in the middle of

June decreased total yearly vegetative productivity.

8.8 Threatened and Endangered Species

The bald eagle was observed several times in the tract vicinity. The raptors were not seen in any present or future development areas, or on Tract C-b. The eagles did not nest nor remain in the area; they were just flying through. Since the area is unsuitable bald eagle habitat and the eagles were just passing through, no further action will be taken except for continued monitoring for bald eagles.

No threatened or endangered plants were found on or near Tract C-b. A permanent herbarium has been established on tract and new plants will be continually added to it as they are found.

In conjunction with the numerous biological studies that will be conducted on and near Tract C-b during all parts of the year, observations confirmed by staff field biologists of any threatened or endangered species will be reported to the AOSO. Appropriate studies to determine significance of a sighting will then be initiated as determined jointly by C-b personnel and AOSO.

8.9 Revegetation

Revegetation monitoring will be conducted on sites which have undergone surface disturbance and on raw shale disposal sites. Revegetation monitoring will be conducted on areas larger than one acre which are seeded with the permanent seed mixture. This monitoring has been completed on sites which meet this criteria and will begin when permanent revegetation projects are completed.

8.9.1 Demonstration Plot

Because of delays in the development schedule the demonstration plot for 1979 will be built in 1980 with shaft oil shale.

9.0 ITEMS OF AESTHETIC, HISTORIC, OR SCIENTIFIC INTEREST

9.1 Aesthetic Values

The C-b Annual Summary & Trends Report (Nov. '74 through Oct. '75) described a study which determined the type and quality of scenic resources in the Tract area. It was concluded that the Piceance Creek Basin has a low scenic value when compared to the other landscape types of the region. Or restated, on a regional basis the Piceance Creek Basin has an extremely low visual character. Nonetheless, actions occurring in the past year include: a) cut-and-fill slopes were laid back and seeded according to the approved monitoring plan; b) buildings have been painted to B.L.M. standards; c) on-site power-line poles are green in color; and d) the main access road was laid out in such a way as to reduce aesthetic impact.

9.2 Historic and Scientific Values

A detailed baseline study of the cultural resources of Tract C-b has been conducted to identify sites of past human activity. (See Volume 1 of the Final Report of the Environmental Baseline Program.) It was concluded that three historic sites do exist on the Tract, (5RB136, 5RB146, and 5RB147) and will be investigated further prior to any development which would disturb them. During the past year, an archaeological team investigated the route for a planned 138 kv powerline from Meeker to C-b Tract. See Figure 9.2-1 for the planned route. No historic sites or remains were located. However, one prehistoric site and five isolated finds were located on or near the powerline right-of-way. Mitigation will be accomplished by avoiding these sites through minor rerouting of the right-of-way.

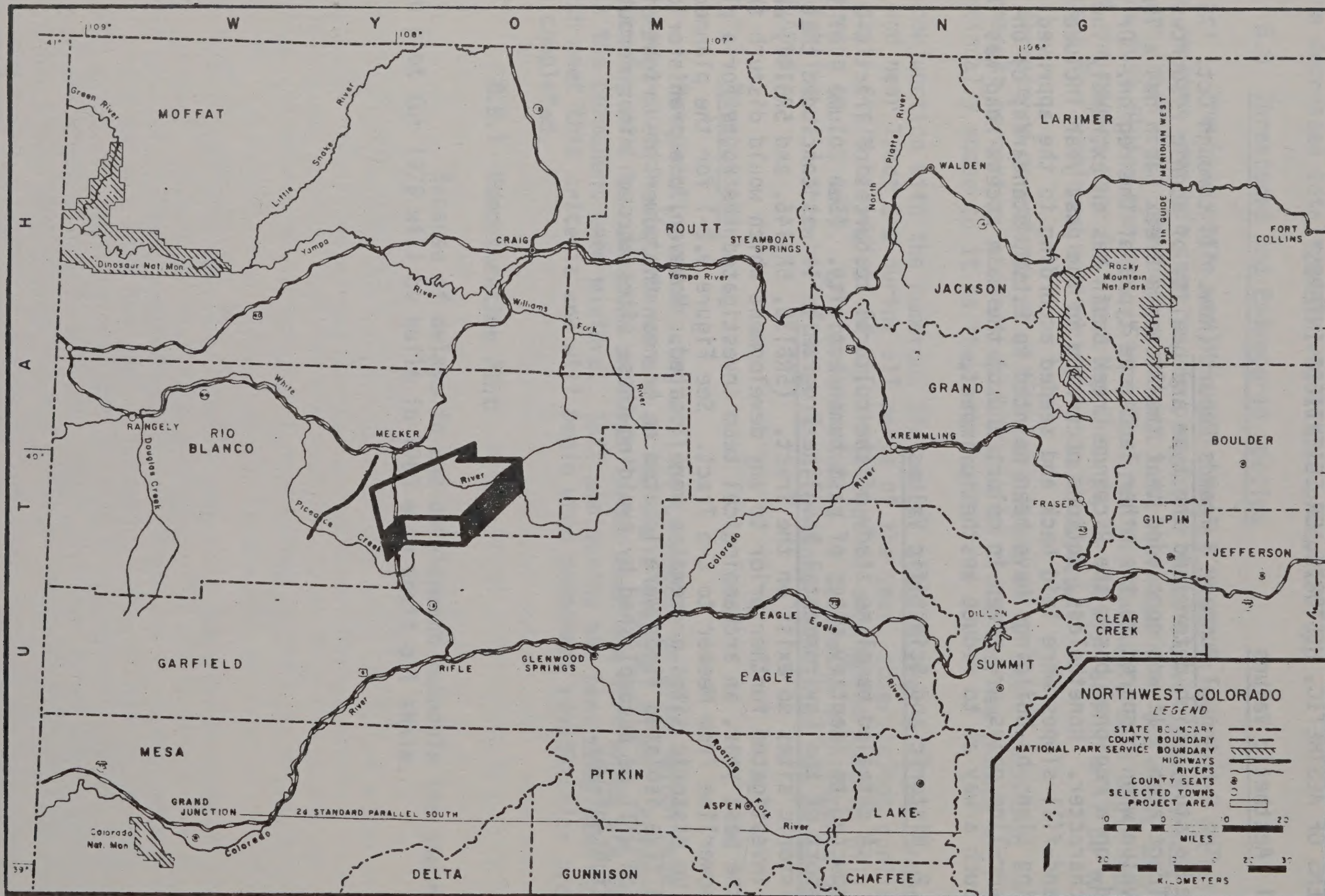

Figure 9.2-1 Planned Powerline Route from Meeker to the C-b Tract

10.0 INDUSTRIAL HEALTH AND SAFETY

10.1 Scope and Rationale

Periodic reports on Health and Safety Activities have been requested by the Area Oil Shale Supervisor. Such reports are those prepared by the C-b Project and all contractors for distribution to outside Federal and State agencies, i.e., Mine Safety and Health Administration (MSHA) and the Colorado Division of Mines and inspection reports made by these agencies and received by the Project and all contractors at the C-b site.

These reports relate to accident frequency analyses, inspection reports and responses, health and safety training, and variance reporting. As received, they are included in the semi-annual data reports.

The C-b project is regulated under the new code of Federal Regulations, Title 30, Part 57, Mine, Safety, Health Administration. We are also governed by the Colorado State Division of Mines laws.

All Contractors on the C-b Site are monitored by the Occidental Safety Department through Ralph M. Parsons Co., our Managing Contractor.

10.2 Accident Frequency Analysis

We have three mine I.D. Numbers on the C-b Site. They are as follows:

1.	Occidental Oil Shale	05-03140
2.	Ralph M. Parsons	05-03148
3.	Gilbert Corp. of Delaware	05-03149

Each I. D. Number is responsible for their own Accident/Incident frequency and severity rate.

Using the MSHA formulas,

$$\text{I.R.} = \text{Injury Rate} = \frac{\text{Number of Accidents X 200,000}}{\text{Hours of Employee Exposure}}$$

$$\text{S.M.} - \text{Severity Measure} = \frac{\text{Days Lost Time X 200,000}}{\text{Hours of Employee Exposure}}$$

the breakdown of accident and severity rate by I. D. Number is as follows:

I.D. # 05-03140 - One lost time accident in 48,988 manhours, resulting in 5 lost time days. This accident resulted in an I.R. = 4.08, for which S.M. = 20.41.

I.D. #05-03148 - This I.D. carries all contractors other than Occidental and Gilbert Corp. They accounted for 2 lost time accidents in 276,166 manhours for an I.R. of 1.44. The 2 accidents resulted in 2 lost time days, thus S.M. = 1.44.

I.D. # 05-03149 - Gilbert Corp. has had no lost time accidents in 117.064 manhours.

The three I.D. Numbers logged 442,218 manhours in 1978 with 3 lost time accidents totaling 7 lost time days for a site I.R. of 1.35 and S.M. of 3.16. Compared to the 1978 national average for underground mines (I.R. - 16.32, S.M. = 23) we have an excellent safety record and plan to improve it in the coming year.

10.3 Inspection Reports & Responses

We have had only 1 MSHA inspection in the past year. It resulted in two minor citations. Colorado Division of Mines inspected the property eight times during 1978. They wrote 18 citations; all citations were abated on the same day they were written.

11.0 SUBSIDENCE MONITORING

The overall objective of the subsidence monitoring program is to determine the effects of underground excavations on the ground surface and on in-situ mining levels.

The surface and underground subsidence caused by mining activities cannot start until significant underground development out from the shaft pillar areas occurs.

The inventory of physical features of the site is being carried out under the aerial photography program described in Section 3.3 of this report.

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12.0 ECOSYSTEM INTERRELATIONSHIPS

12.1 Introduction

Indicator variables for Development Monitoring are given in the Development Monitoring Plan. Also listed are perturbations that affect the magnitude of these variables and the environmental consequences (or impacts) of these perturbations. Examples of perturbations include mining, retorting, shale disposal, waste disposal, etc. Environmental consequences may affect other indicator variables; such relations of indicator variables with other indicator variables are to be analyzed and are called ecosystem interrelationships.

Ecosystem interrelationships are not monitored or measured directly. They are inferred from three principal techniques: 1) expert judgment resulting from baseline observations of two or more variables, 2) correlative statistics, and 3) predictive ecosystem modeling. Aspects of all three have been gleaned from the baseline studies and reported in Volume 5, System Interrelationships, Environmental Baseline Program Final Report and its Appendix F, User's Reference Diagrams (1977). In particular, baseline judgment has been utilized to obtain the comprehensive "effects matrix" (Figure A12.1-1).

With regard to the comprehensive "effects matrix." so-called effect generators (driving variables, perturbations, state variables) are listed across the top (matrix columns) and effect receptors (abiotic and biotic components and processes) are listed at the side as matrix rows. Entries in the matrix are the following interrelationships: direct effects, indirect effects, both direct and indirect, and effects of particular concern. Forty-five (45) updated effects of particular concern have been transposed to Table 12.1-1 of this report.

The matrix will be periodically updated to include additional relationships needed to assess impacts of development.

The interrelationships of Table 12.1-1 and others defined as new monitoring results will be analyzed in the future and subjected to correlative statistical techniques as a means of defining those interrelationships of major concern. Subsequent monitoring can then concentrate on these.

12.2 "Candidate" Interrelationships

The above considerations provided insights into specific interrelationship "candidates" for early study. The screening consisted of three phases: (1) qualitative, (2) initial quantitative, and (3) refined quantitative.

The qualitative phase consisted in identifying the dependent variable(s) and all major independent variables, both natural and man-induced perturbations. Too many gaps in the data precluded quantitative analysis at this time. However, a purpose was still served in that it pointed the way for future increased sampling rigor and uniformity. Then, provided the data were deemed

TABLE 12.1-1 MAJOR ECOSYSTEM INTERRELATIONSHIPS

EFFECT RECEPTORS \ EFFECT GENERATORS	PRECIPITATION	AIR TEMPERATURE	BORON (Water)	SO_2 (Air)	NO_x (Air)	OZONE (Air)	FLUORIDE (Water)	TRACE ELEM. (Air)	NOISE	DISTURBED VEG.	UNREVEG. BARE AREAS	EROSION	MIXED SOIL PROFILE	ALTERED SOIL CHEM.	SEDIMENT	ALTERED SURF. WATER FLOW	WATER TABLE ALTER.	ALTERED WATER QUAL.
RUNOFF	X										X	X			X			
STREAMFLOW												X					X	
GROUNDWATER FLOW																	X	
PLANT GROWTH	X	X	X	X	X	X	X	X						X		X		
LITTER DECOMP.				X														
ANIMAL GROWTH	X	X	X				X	X										
REPRODUCTION									X									
ANIMAL MOVEMENT									X									
AQUATIC PLANT GROWTH			X				X								X	X		X
AQUATIC VERT. GROWTH															X	X		X
AQUATIC VERT. MORT.																		X
AQUATIC INVERT. GROWTH															X	X		
AQUATIC INVERT. MORT.																		X
SOIL CHEM. & pH								X										
WATER QUALITY																	X	
ANIMAL TISSUE							X											
GEN. HABITAT									X	X	X							
REVEGETATION													X	X				

complete enough, quantitative analyses were attempted. Refined quantitative analyses will be undertaken in future years.

At this writing three candidates have "survived" the qualitative screen and initial quantitative analysis attempted. These are:

(1) Effects of climatic variations on herbaceous productivity. When the "land treatment" system is initiated its effects will be included.

(2) Effects of traffic on Piceance Creek road, snow depth, and deer population on deer road kill.

(3) Effects of "urbanization" (from unrevegetated or surfaced areas) on watershed hydrologic response time.

Other interrelationships subjected to qualitative study included:

(4) Effects of herbivore density on shrub utilization.

(5) Hunting and trapping pressure on coyote and rabbit interrelationship.

(6) Deer mortality vs. shrub production and utilization.

Increased sampling rigor and/or uniformity will be sought to enhance the possibility of quantitative results in the future.

These six "near-term" interrelationships are discussed in the following paragraphs:

12.3 Specific Near-term Interrelationships

12.3.1 Effects of Climatic Variations on Herbaceous Productivity

12.3.1.1 Qualitative Judgements

It is expected that herbaceous productivity increases with increasing precipitation and increased length of the growing season. Specific precipitation measures suggested are:

(1) total annual precipitation of the current year.

(2) total annual precipitation of the previous year, especially late season precipitation

(3) precipitation temporal distribution over
(a) Mar - Apr - May or
(b) Apr - May - June or
(c) May - June - July or

(4) abnormal rates of precipitation

Growing season candidate variables include:

(1) length of the growing season

(2) total degree - days during the growing season

(3) degree - day temporal distribution over

(a) Apr - May - June
(b) May - June - July
(c) June - July - Aug
(d) July - Aug - Sept

12.3.1.2 <u>Quantitative Analysis</u>

It is instructive to point out that it is next to impossible to obtain a highly accurate total of annual precipitation in a harsh, remote area at any one site. Therefore, monthly average values in the Tract vicinity were obtained and summed over 12 months to obtain average annual totals in the Tract vicinity. Table 6.3.1-3 of Chapter 6 presents average annual total precipitation, with and without the microclimate stations (i.e. stations under canopies). Also presented on the same table are three-month "sliding" precipitation distribution and peak precipitation events. Figure 6.3.1-3 of Chapter 6 presents monthly precipitation histograms in combination with related growing season spans. Table A6.3.1-3 presents total degree-days, three month sliding degree-days and growing season dates and spans.

The following herbaceous productivity sites were selected for analysis:

BJ02 - Chained Pinyon Juniper (Control)
BJ05 - Pinyon Juniper Woodland (Future Development)

A simple tabular approach was utilized whereby for each of the four years productivity was ranked from highest to lowest (1 to 4 respectively) as were each of the remaining independent variables. Those coming closest to the productivity rank order are presented in Table 12.3.1-1. Degree-days did not correlate positively and are not shown; as a matter of fact, the year with the lowest productivity had the highest degree-days and the highest or second highest productivity year corresponded to the lowest degree-days.

Quantities which rank-correlated best with productivity and are plotted on Figure 12.3.1-1 are:

1) precipitation during April-May-June
2) precipitation of the previous year
3) length of the growing season
(with one anomaly - when it rained too late to be of use)

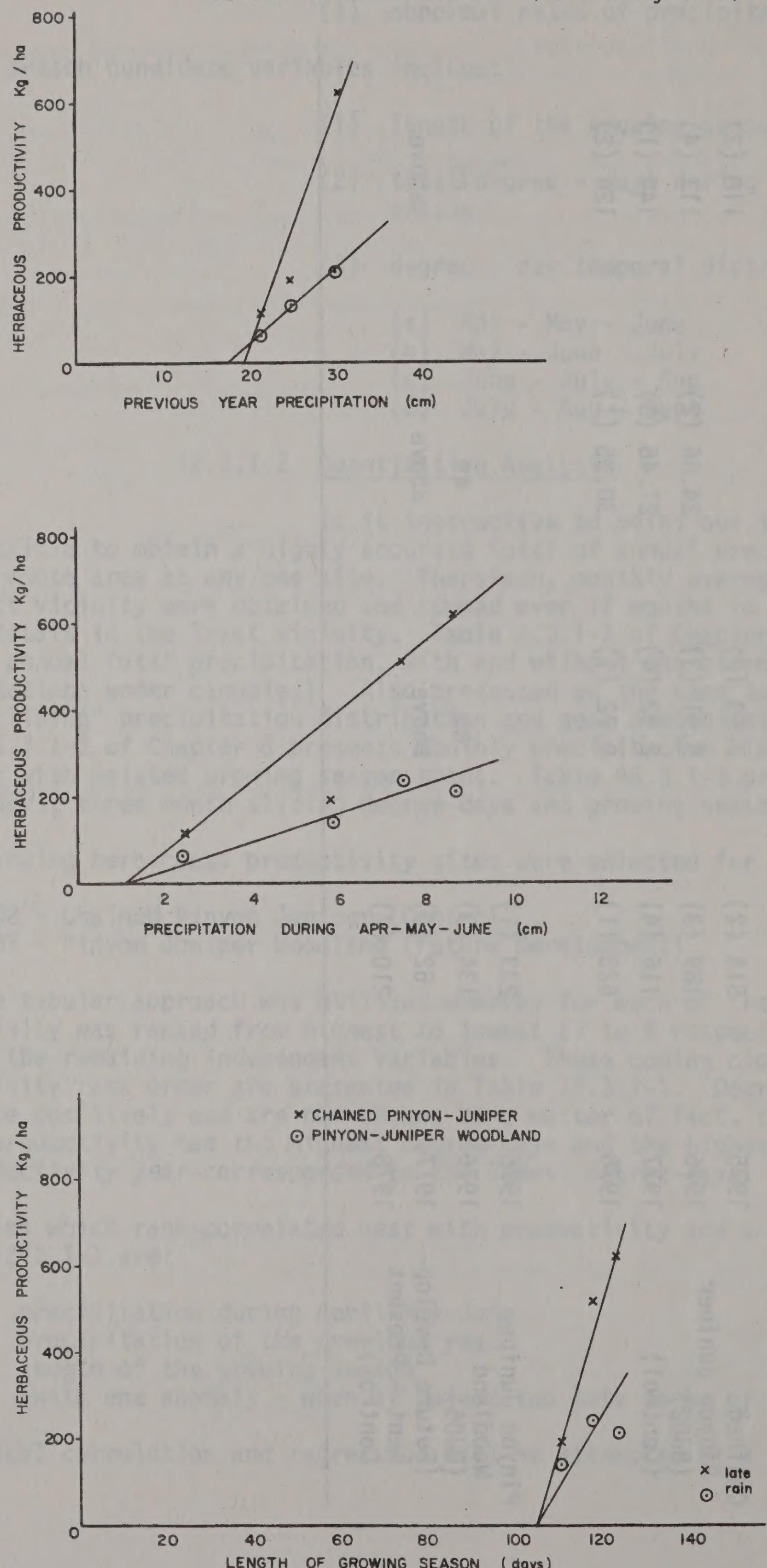
Statistical correlation and regression will be attempted at a future date.

TABLE 12.3.1-1 "RANKING" OF INDEPENDENT VARIABLES WITH PRODUCTIVITY

(1)→(4) = Rank from Top to Bottom

Site	Year	Productivity (kg/ha)	April-May -June Ppt (cm)	Total Ppt. of Previous Year (cm)	Growing Season (Days)
Chained Pinyon Juniper (BJ02) (Control)	1975	514 (2)	7.53 (2)	-	118 (3)
	1976	189 (3)	5.91 (3)	24.86 (2)	111 (4)
	1977	116 (4)	2.52 (4)	21.46 (3)	144 (1)
	1978	623 (1)	8.72 (1)	30.35 (1)	124 (2)
Pinyon Juniper Woodland (BJ05) (Future Development - Present Control)	1975	233 (1)			
	1976	134 (3)	as	as	as
	1977	62 (4)	above	above	above
	1978	210 (2)			

FIG. 12.3.1-1 HERBACEOUS PRODUCTIVITY vs GROWING SEASON & PRECIPITATION (1975 through 1978)



12.3.2 Effects of Traffic, Snow Depth and Deer Road Count on Deer Road Kill

12.3.2.1 Qualitative Judgments

The dependent variable in this interrelationship is the number of deer killed by vehicles. The independent variables include: traffic along the Piceance Creek highway, deer population and movements, and the climate as characterized by snow depth and precipitation or snowing rates. A total of 125 deer were killed along the Piceance Creek highway from September 1977 to May 1978. Traffic estimates have been difficult to obtain due to the inclement weather causing equipment failure (snowplows cutting road-counter hoses, etc.)

Some general observations are: more deer are killed during the fall migration and during the spring green-up than during the winter months. Fewer deer are killed under poor weather conditions, probably because vehicles are moving slower and there is less deer movement. Deer are killed over the entire length of the Piceance Creek highway.

12.3.2.2 Quantitative Analyses

12.3.2.2.1 Scope and Rationale

The specific factors which must influence deer road-kill include traffic along various segments of Piceance Creek Road, snow depth, precipitation, work force, weekly deer count and weekly deer road-kill. Interrelationships determined among these will be used in the formulation of mitigative measures. Annual monitoring begins in mid-September and ends in April or May when deer have migrated to the highlands.

12.3.2.2.2 Objectives

The objectives of this study are:

1. To evaluate the interrelationships of traffic load, mitigative measures, time of year, deer movements, and climate on deer road-kill.

2. Review existing monitoring efforts and determine how they may be improved.

3. Use information gained from study and analysis to formulate other possible mitigative measures.

12.3.2.2.3 Experimental Design

Weekly samplings of deer road count and road-kill are obtained each year beginning in mid-September and continuing through May. Tabulations are for one-mile intervals along the 41-mile stretch of Piceance Creek Road between Rio Blanco and White River City (Highway 64).

Traffic counters are placed across Piceance Creek Road near Rio Blanco and at White River City, at the access road entrances to C-b and C-a tracts, and across Piceance Creek Road between the access roads. A count of incoming vehicles (excluding buses) is kept at the C-b guard gate.

Precipitation measurements are recorded hourly at several stations on and near the tract. Snow depth measurements are taken bi-weekly starting on December 1. For this study precipitation measurements from station AB20 and snow depth measurements from stations BC08 and BC09 are used because these stations are near Piceance Creek Road.

Passenger buses run round trips for all work shifts between Rifle and the C-b tract and between Meeker and the C-b tract. Daily records are kept of the number of passengers and number of buses.

12.3.2.2.4 Method of Analysis

Data used in this study are from records beginning September 21, 1978 and ending March 16, 1979.

Scatter plots were used to identify possible correlations between the deer-kill as the response variable and deer road count, traffic, precipitation and snow depth as independent variables. All data were grouped and averaged to correspond with the weekly deer-kill records. These variables were further examined for potential interrelationships utilizing computer programs for partial correlations and multiple linear regression. Outputs of the programs provide analyses for evaluating statistical significance of these interrelationships and some of the outliers in the scatter diagrams. Outliers are data observations with extreme values relative to the remaining observations.

12.3.2.2.5 Results and Discussion

(a) <u>Correlation Analyses</u>

Scatter diagrams depicting the relationships between the study variables are shown in Figures A12.3.2-1, A12.3.2-2, A12.3.2-3, and A12.3.2-4.

Using the correlation coefficient (r) and converting to t-score by the formula

$$t_1 = r \,/\, \left((1-r^2) \,/\, (n-2) \right)^{\frac{1}{2}}$$

the results summarized in Table 12.3.2-1 were noted.

The correlation coefficients are lower than might be expected. The only significant correlation is that between deer road count and road kill. Correlations between deer-kill and precipitation and snow depth, although not significantly different than zero, are negative indicating a very weak inverse relationship and lend weak support to the qualitative observation that road-kills are fewer with poor weather conditions.

Table 12.3.2-1

SUMMARY OF CORRELATION ANALYSIS

1. deer kill vs. deer road count $r = 0.4064$

   $t_1 = 2.1331 \quad > t\ (23, 0.95) = 2.064^*$ significant

2. deer kill vs. traffic $r = -0.2269$

   $t_1 = 1.1173 \quad < t\ (23, 0.95) = 2.064^*$ not significant

3. deer kill vs. precipitation $r = -0.2064$

   $t_1 = 1.0116 \quad < t\ (23, 0.95) = 2.064^*$ not significant

4. deer kill vs. snow depth not calculated because of low correlation

   $r = 0.0781$

   not significant

* t obtained from standard statistical table with 23 degrees of freedom and 95 percent confidence interval. If t_1 is greater than t, then the correlation between the two parameters is significant.

The correlations are influenced by a few outliers. In this case the outliers were high road-kill counts in March. These outliers are explained by the movement of the deer to the slopes when the snow starts to melt. The change in the weather also melts the ice off the road and results in increased traffic speed, a probable factor in the road-kill count.

(b) Regression Analyses

Multiple regression analyses were performed to obtain predictive relationships between the responsive variable, deer-kill, and the independent variables. These analyses were considered insignificant when relationships could not be clearly defined for snow depth, precipitation and traffic count. The correlation coefficient shows the relationship to deer count as the greatest. See Tables A12.3.2-1, A12.3.2-2, and A12.3.2-3. Using a backward elimination procedure with deer kill regressed on deer road count, traffic, and precipitation (as the independent variables), the results are shown in Table 12.3.2-2. This result is identical with results of the previous correlation analysis; i.e. deer kill correlated only with deer road count.

Table 12.3.2-2

SUMMARY OF REGRESSION ANALYSES

1. deer road count, traffic precipitation

   $F_1 = 1.6492 < 3.07 = F(3, 21, 0.95)$* not significant

2. deer road count, traffic

   $F_1 = 2.1803 < 3.44 = F(2, 22, 0.95)$* not significant

3. deer road count

   $F_1 = 4.5497 > 4.28 = F(1, 23, 0.95)$* significant

* F-statistic from standard statistical tables; if F_1 is greater than F then the result is significant.

The non-significant F-scores can be attributed to the lack of good traffic data. The best data and those used were from the guard gate count. Traffic monitors on Piceance Creek Road were frequently cut by snow plows in inclement weather.

(c) Other Analyses

Using deer count by mile, a ratio of deer kill to deer road-count was determined for three segments of Piceance Creek Road as shown in Table 12.3.2-3.

Table 12.3.2-3

SUMMARY OF DEER ROAD-COUNT AND ROAD-KILL BY ROAD SEGMENT

Road Segment	Road Kill	Road Count	Ratio	Percent of Traffic*
Rio Blanco to C-b	69	4527	0.0152	54%
C-b to C-a Access Road	13	1397	0.0093	incl.
C-a Access Road to White River City	21	1146	0.0183	13%
Rio Blanco to C-a Access Road	82	5924	0.0138	27%
Other Oil Shale Employee Traffic	incl.	incl.	--	6%
Other Piceance Creek Traffic	incl.	incl.	--	?

* Traffic based on combined C-a and C-b employee estimates of 446.
incl. - means included in other segments.

The low ratio of kill to road-count on the section of Piceance Creek Road between the C-a and C-b access roads can be explained by the terrain. The other two sections have gentler terrain on both sides of the road.

Bus passenger reports from September 1, 1978 to January 31, 1979 were summarized into round trips per week in Table 12.3.2-4.

Table 12.3.2-4

SUMMARY OF BUS STATISTICS

Total passengers for 21.86 weeks	23,340
Average passengers per week	1,068
Total bus trips for 21.86 weeks	524
Average bus trips per week	24

Although no prediction of deer saved is possible without adequate traffic data and passenger-per-vehicle data, it is apparent that a substantial number of passenger vehicle-round-trips per week are being saved through bus use. For example, the average number of passengers which ride the bus per week indicates a savings of 332 vehicle-round-trips per week, if there is an average of three passengers per vehicle. If there is one passenger per vehicle, a savings of 1044 vehicle-round-trips per week is the result of the bus service.

12.3.2.2.6 Conclusions and Recommendations

Based on the available data, the scatter diagrams, correlation, and regression analyses show the only variable influencing the number of deer killed was the deer road-count. Yet, it seems natural that deer road kill is related to traffic and hence the reduction of traffic by providing buses is a significant factor in reducing deer road-kill. Also, the climate, condition of deer killed, and location where deer are most likely to be on the road may be shown to be significant when better data are available. When any of these factors are found to be significant, additional mitigative measures may be formulated.

The following changes in the experimental design have been implemented or are recommended in order that the interrelationships with these variables and deer kill can be more accurately determined.

1. Starting in March 1979, the deer mortality reports will include a marrow condition. This may establish a relationship between deer condition and road kill.

2. Magnetic loop counters are being obtained to replace counter hoses as traffic monitors. These monitors will be placed at positions designed to relate traffic count to deer kill count by road segment.

3. Deer kill and traffic counts may be made daily for a short period of time to permit a more detailed study of the interrelationship. When traffic counts were averaged by week to correspond with weekly deer kill counts, daily variations in traffic count related to week-ends or holidays were lost.

4. An estimate of time of day deer are killed should be made when possible. Analysis of these data may indicate possible mitigative measures such as a change in hours at which shift changes occur.

5. From guard gate inquiries or employee surveys, an average number of passengers per vehicle should be obtained. This information could be used with employee route information determined from residence and bus service data to perform correlation studies of deer count and deer road kill with traffic.

6. Traffic speed controls should be considered during periods of high road kill and on road segments of high road kills.

It would appear that the implementation of the above additions to the experimental design will yield sufficient data to evaluate the interrelationships of traffic load, mitigative measures, time of year, deer movements, and climate, on deer road kill. With this knowledge additional mitigative measures might be formulated. If a quantitative relationship between increased traffic and road kill were determined, it would be possible to predict the number of deer which are saved by the bus service and any additional mitigative measures formulated.

12.3.3 Effects of Urbanization on Hydrologic Response Time

12.3.3.1 Scope and Rationale

Hydrologic response of a stream to a precipitation event or successive bursts of rainfall may be determined through comparison of the hyetograph and hydrograph produced by a given storm. A hyetograph is a plot of rainfall rate versus time. A plot of runoff rate versus time yields a hydrograph.

Precipitation which reaches the ground surface may infiltrate or flow over the land as runoff. Runoff contributed by various portions of the drainage basin will be incorporated into the hydrograph characteristic of a given point on the stream at different times. If the hyetograph and hydrograph are plotted on the same graph, the centroid lag, or lag time, can be determined. The lag time is the difference between times at which 50 percent of the total accumulation of both variables has occurred.

The lag time of a basin can be expected to decrease with increased urbanization. Paving, clearing and building could decrease infiltration and increase runoff and flood peaks.

12.3.3.2 Objectives

Although development of C-b Tract is anticipated to cause a minimum of surface disturbance, study of lag times throughout development may provide a measure of surface impact.

12.3.3.3 Experimental Design

Records of stream flow and precipitation for a storm on at least an hourly basis are necessary to determine lag times. Although gauging stations are equipped with continuous flow recorders, only daily-average flows are published. The USGS Water Resources Division in Meeker provides hourly values on request. Flow data for Stations WU61, WU58, WU42, WU39, WU36, and WU22 would be appropriate for studies of hydrologic response time. Station AB20, operated by C-b Tract, measures precipitation on an hourly basis during storms. Records of the amount of disturbance of Tract acreage on an annual basis are necessary to relate urbanization to hydrologic response time.

12.3.3.4 Method of Analysis

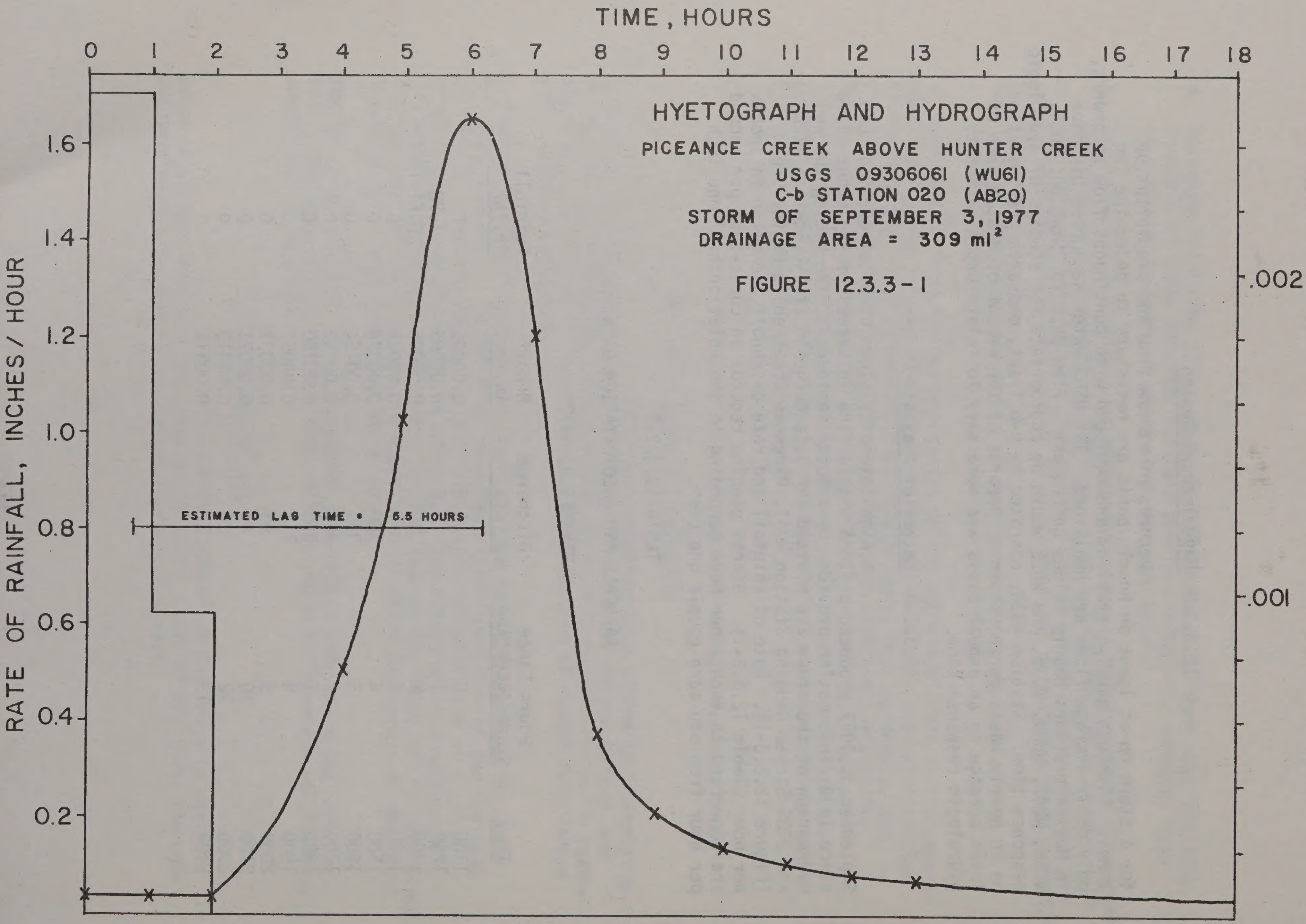
A high-intensity storm of brief duration on September 3, 1977 produced a flood with a flow in excess of any other flood since 1939 (information provided by a local resident). The hyetograph and hydrograph of the storm are plotted for data gathered at C-b Station AB20 and USGS Stream Gauging Station WU61, Piceance Creek above Hunter Creek (Figure 12.3.3-1). Rate of rainfall and rate of runoff are given in inches per hour (Table 12.3.3-1). Stream gauging records in cubic-feet per second are converted to inches per hour according to the relationship "one inch per hour from one acre equals one cfs".

Table 12.3.3-1

RAINFALL AND PRECIPITATION DATA

SEPTEMBER 3, 1977

Time	Hours Since Storm Inception	Discharge cfs	Runoff in./hr.	Rainfall in./hr
1100	0	9.6	0.00005	0
1200	1	9.6	0.00005	1.70
1300	2	10	0.00005	0.61
1400	3	55	0.00028	0
1500	4	150	0.00076	0
1600	5	305	0.00154	0
1700	6	480	0.00243	0
1800	7	355	0.00180	0
1900	8	113	0.00057	0
2000	9	63	0.00032	0
2100	10	41	0.00021	0
2300	12	25	0.00013	0
2400	13	22	0.00011	0


TIME, HOURS
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
HYETOGRAPH AND HYDROGRAPH
PICEANCE CREEK ABOVE HUNTER CREEK
USGS 09306061 (WU61)
C-b STATION 020 (AB20)
STORM OF SEPTEMBER 3, 1977
DRAINAGE AREA = 309 mi²
FIGURE 12.3.3-1
ESTIMATED LAG TIME = 5.5 HOURS
RATE OF RAINFALL, INCHES / HOUR
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
RATE OF RUNOFF, INCHES / HOUR
.002
.001

12.3.3.5 Results and Discussion

An estimate of the lag time of the drainage area upstream of the gauging station (309 sq. mi.) is approximately 5.5 hours. Additional storms will be studied to refine lag time estimates and to estimate possible future effects of urbanization on this parameter.

12.3.3.6 Conclusions

Although the Piceance Creek gauging station above Hunter Creek was used as an example, stations in the C-b Tract drainages should be evaluated for lag time as stream flow records lengthen to more accurately gauge possible effects of Tract development.

12.3.4 Effects of Herbivore Density on Shrub Utilization

12.3.4.1 Qualitative Judgments

The dependent variables are (cattle and deer) herbivore densities. Independent variables include: climate data, road counts, age and sex counts, shrub production and utilization results and lagomorph abundance. This information is gathered from developmental and control transects, micro-climate stations and various deer counts.

Some general conclusions that can be made at this time are:

* Cattle use has not changed appreciatively in the last four years.
* Mule deer road count studies showed a spatial seasonal pattern almost identical to the past three years of study.
* Baseline-condition evaluations of mule deer pellet-group distribution and density studies are continuing at this point in time. Transect locations which have been operative over the past two years have indicated very similar patterns of habitat use.
* Production and utilization estimates of bitterbrush and mountain mahogany for this past year differed markedly from 1976-77 estimates in that production was lower and utilization was much higher. Yearly patterns of mule deer habitat use as revealed by these data are not as similar as patterns revealed by pellet-group data.
* When precipitation decreased, browse production tends to decrease, but utilization tends to increase.

12.3.5 Hunter and Trapping Pressure on Coyote-Rabbit Interrelationships

12.3.5.1 Qualitative Judgments

Hunting and trapping pressure is the dependent variable which could influence coyote-rabbit interrelationships include raptor, small mammal, deer, coyote, and rabbit populations, and climate.

Conclusions to date are:

* There is very little rabbit hunting on or near the Tract.
* Coyotes were trapped in October in West Stewart Gulch.
* Raptor abundance has not changed significantly over the last four years.

Difficulties in quantifying hunting pressure exist. Intensified contacts to be pursued in this regard are Dept. of Wildlife and neighboring ranchers.

12.3.6 Deer Mortality versus Shrub Production and Utilization

12.3.6.1 Qualitative Judgments

Deer mortality is the dependent variable. Variables influencing deer mortality include: deer population and movements, climate, and shrub production and utilization.

Deer mortality data is collected on ten permanent study plots. Some general conclusions that can be made at this time are: past sampling showed that sampling in selected sagebrush draws was just as informative as sampling random plots in all habitat types on or around Tract C-b.

Since several new draws were added to the study since baseline, detailed analysis could not be done. Some results found this year were: (1) Possibly due to the mild winter, there were fewer dead deer per hectare than in previous years; (2) Fawns comprised 80% of the deer carcasses found this year.

13.0 NOTES

13.1 Conversion Factors

An attempt has been made to report all studies and data in metric units. In most cases these data are collected and initially tabulated in English units and a few analyses were carried out with English units. Table 13.1-1 contains conversion factors for converting from English to metric units. Conversion from metric to English units can be made by dividing by the factor or by multiplying by its reciprocal.

Table 13.1-2 presents additional conversion factors useful with interpretation of data reported herein.

13.2 Literature Cited

Table 13.2-1 is a bibliography of literature cited in the text. Reference in the text is by author or title.

Table 13.1-1

TABLE OF CONVERSION FACTORS

To Convert From	To	Multiply By
acres	ft^2	4.3560×10^4
acres	hectares	0.404687
atmospheres	$dynes/cm^2$	1.01325×10^6
atmospheres	bars	1.01325
atmospheres	mm H_g	760
atmospheres	$newtons/m^2$	1.01325×10^5
atmospheres	lbs/ft^2	2116.32
bars	atmospheres	0.98692
bars	mb	1000.00
bars	$newtons/m^2$	10^5
BTU (British Thermal Units)	gm. cal.	252.
cfm	liters/sec.	0.4720
cfs	m^3/s	0.028317
degrees Fahrenheit	degrees Kelvin	$(^oF-32)*(5/9) +273$
degrees Fahrenheit	degrees Centigrade	$(^oF-32)*(5/9)$
degrees	radians	0.017453
feet	meters	0.3048
ft^2	meters	0.092903
$ft^3/min.$	$m^3/sec.$	0.000472
ft^3	gals	7.481
ft^3	m^3	0.028317
gals	m^3	0.0037854
gals	liters	3.7853
gals/min	$m^3/sec.$	0.00006309
gals/min	liters/sec.	0.069088
grains	grams	0.064798918
grains	pounds	1.42857×10^{-4}
hectares	m^2	10^4
inches	cm	2.5400
$inch^3$	cm^3	16.3872
miles	kilometers	1.60935
mph	mps	0.44703
pounds	kilograms	0.45359
pounds/acre	kg/ha	1.12173
pounds/hour	grams/sec.	0.1260
$pounds/inch^2$	atmospheres	0.068046
$pounds/inch^2$	mb	68.947
radians	degrees	57.29578
rods	meters	5.0292
SCFM (Standard Cubic Ft/Min)	ACFM (Actual cubic ft./min)	$(^oK_a/^oK_s)(P_s\ mb/P_a\ mb)$
ton (short)	kilograms	907.185

Table 13.1-2

ADDITIONAL CONVERSION FACTORS
MULTIPLES AND SUBMULTIPLES OF UNITS

Factor by Which Unit is Multiplied	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	m
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

CONVERSION FACTORS FOR GASES

Molecular Weight (MW)	Pollutant	To Convert µg/m^3 at 25°C and 760 mmHg to ppb Multiply by Factor
46.01	NO_x as NO_2	.532
30.01	NO	.815
46.01	NO_2=NO_x -NO	.532
64.06	SO_2	.382
34.08	H_2S	.718
-	THC	1.530
16.01	CH_4	1.525
28.01	CO	.873
48.00	O_3	.510

Equation: $$\frac{22.414}{MW} \left(\frac{298}{273}\right) = \text{Factor}$$

Table 13.2-1

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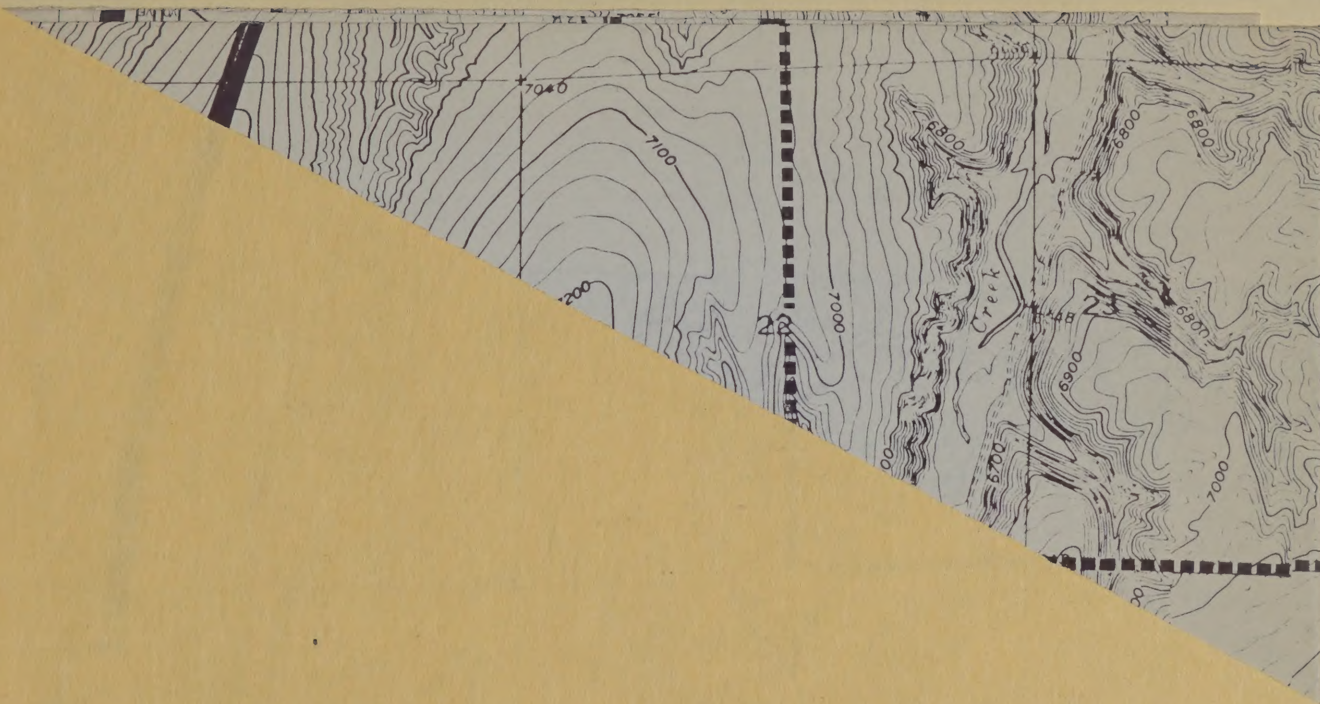
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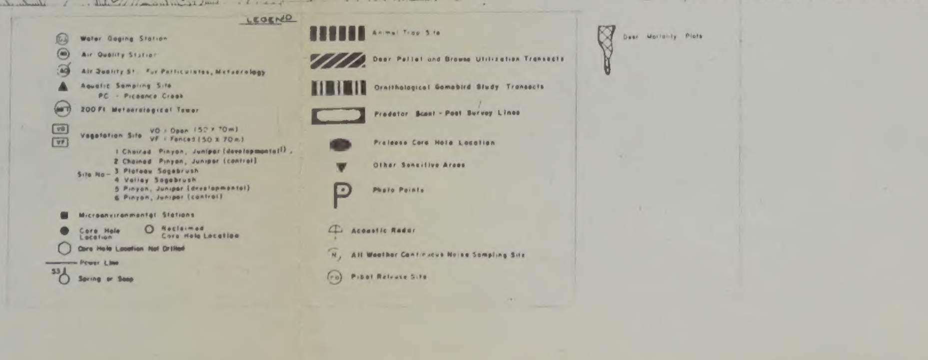
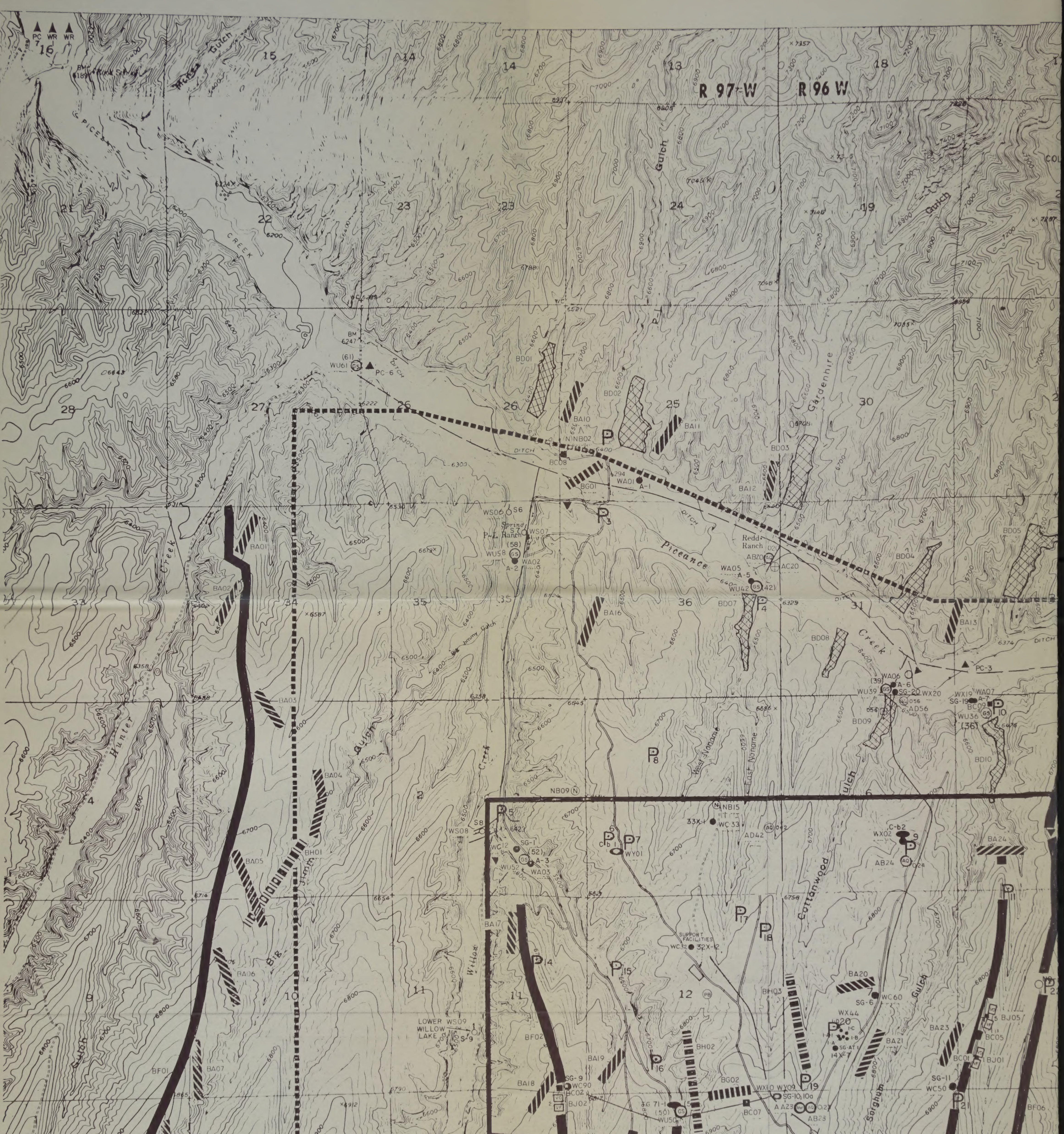


DEVELOPMENT
MONITORING
ACTIVITIES

REVISION I
MAR 8, 1979



R 97 W
R 96 W
Piceance Creek
Gardenhire Gulch
Redd Ranch
P-L Ranch
Spring
Hunter Creek
Willow Creek
Cottonwood Gulch
Sorghum Gulch
West Nonome
East Nonome
DITCH
SUPPORT FACILITIES
LOWER WILLOW LAKE
UPPER WILLOW LAKE
PC-6
PC-3
BA01
BA02
BA03
BA04
BA05
BA07
BA08
BA09
BA10
BA11
BA12
BA13
BA16
BA17
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BD02
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BD09
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BF01
BF02
BF05
BF06
BG01
BG02
BH01
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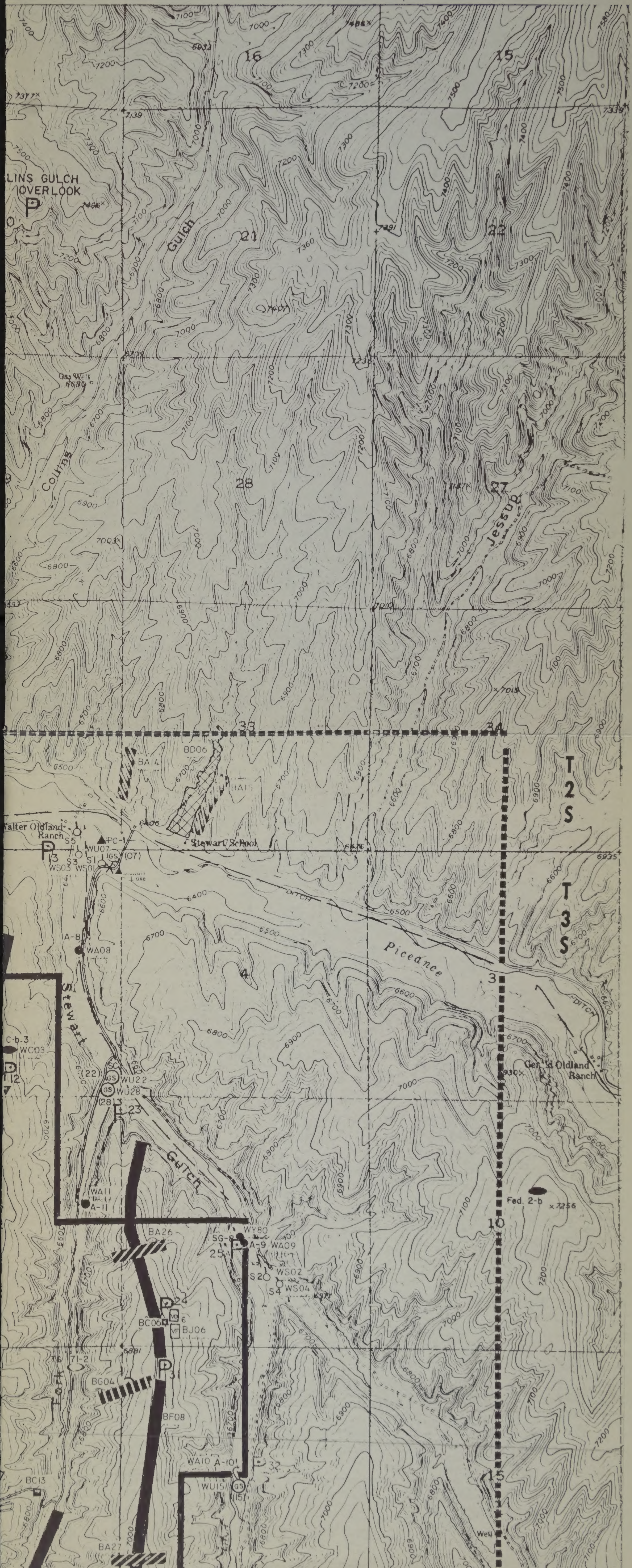
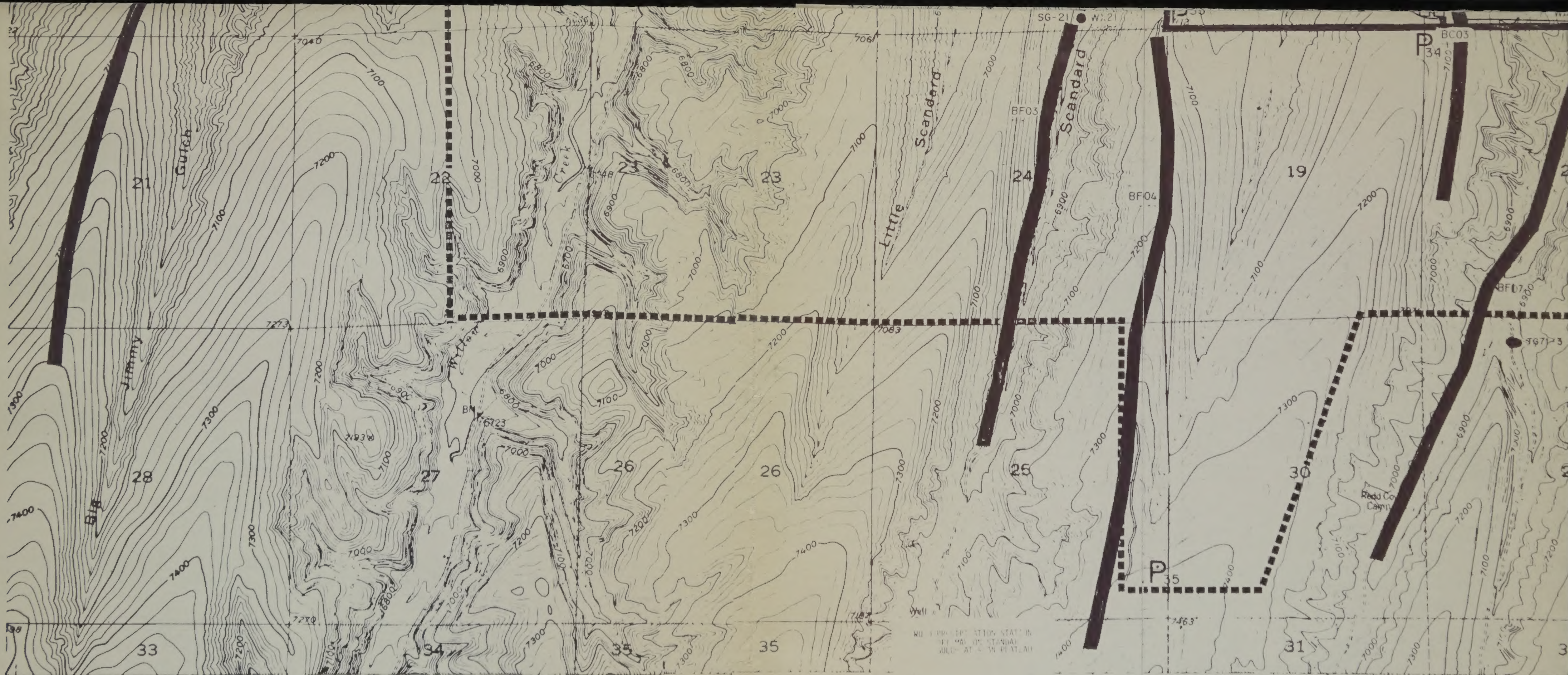


LINS GULCH
OVERLOOK
Gulch
Colrins
Jessup
T 2 S
T 3 S
Walter Oldland
Ranch
Stewart School
DITCH
Piceance
Stewart
Gulch
Fork
Ger. d Oldland
Ranch
Fed. 2-b
Well
16
15
21
22
28
27
33
34
4
3
10
15
BA14
BD06
PC-1
WU07
WS03
WS01
A-8
WA08
C-b-3
WC03
WU22
WU28
WA11
A-11
BA26
SG-8
WY80
A-9
WA09
WS02
WS04
BC06
BJ06
BG04
BF08
WA10
A-10
WU15
BC13
BA27
SG-17
WU25



DEVELOPMENT MONITORING ACTIVITIES

REVISION I
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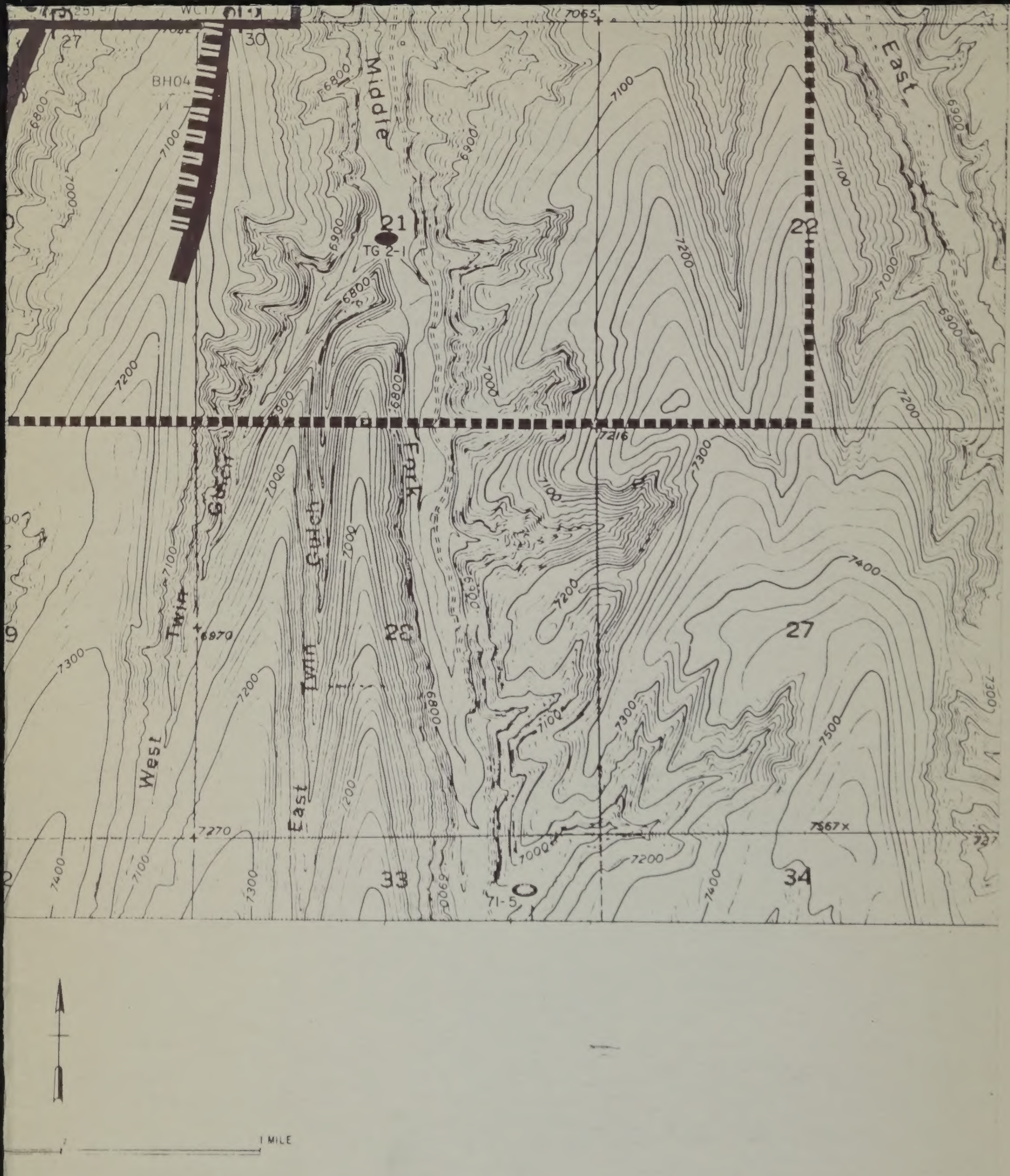
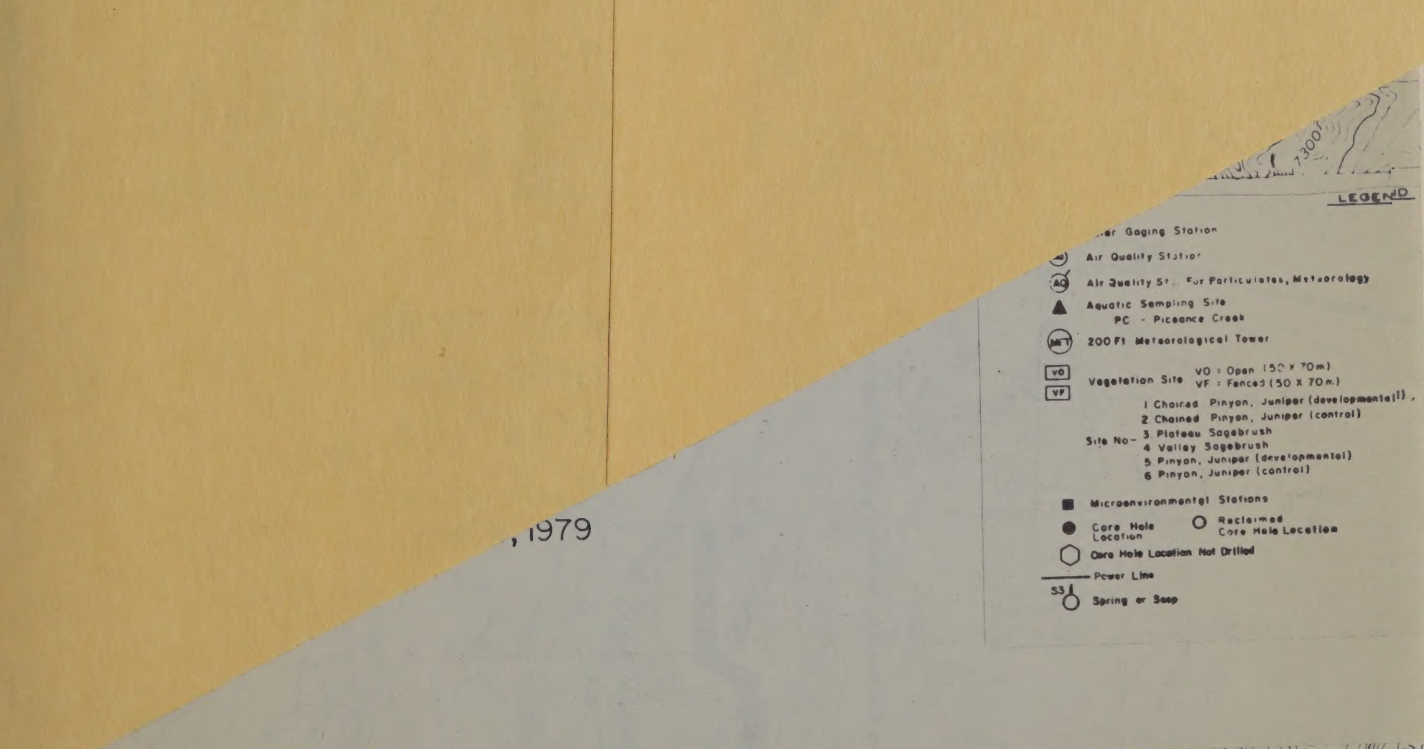
LEGEND

- Water Gaging Station
- Air Quality Station
- Air Quality St. For Particulates, Meteorology
- Aquatic Sampling Site
  - PC - Piceance Creek
- 200 Ft Meteorological Tower
- Vegetation Site VO = Open (50 x 70m) VF = Fenced (50 x 70m)
  - Site No -
    1. Chained Pinyon, Juniper (developmental),
    2. Chained Pinyon, Juniper (control)
    3. Plateau Sagebrush
    4. Valley Sagebrush
    5. Pinyon, Juniper (developmental)
    6. Pinyon, Juniper (control)
- Microenvironmental Stations
- Core Hole Location
- Reclaimed Core Hole Location
- Core Hole Location Not Drilled
- Power Line
- Spring or Seep
- Animal Trap Site
- Deer Pellet and Browse Utilization Transects
- Ornithological Gamebird Study Transects
- Predator Scent - Post Survey Lines
- Prelease Core Hole Location
- Other Sensitive Areas
- Photo Points
- Acoustic Radar
- All Weather Continuous Noise Sampling Site
- Pibal Release Site
- Deer Mortality Plots


Middle
East
Fork
West Twin Gulch
East Twin Gulch
BH04
TG 2-1
71-5
21
22
27
28
30
33
34
7065
7216
6970
7270
7567 x
6800
6900
7000
7100
7200
7300
7400
7500
1 MILE



, 1979
LEGEND
Gaging Station
Air Quality Station
Air Quality St.. For Particulates, Meteorology
Aquatic Sampling Site
PC - Piceance Creek
200 Ft Meteorological Tower
Vegetation Site VO : Open (50 x 70m) VF : Fenced (50 X 70m)
Site No- 1 Chained Pinyon, Juniper (developmental), 2 Chained Pinyon, Juniper (control) 3 Plateau Sagebrush 4 Valley Sagebrush 5 Pinyon, Juniper (developmental) 6 Pinyon, Juniper (control)
Microenvironmental Stations
Core Hole Location
Reclaimed Core Hole Location
Core Hole Location Not Drilled
Power Line
Spring or Seep